THE No 1 UK MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EPE EVERYDAY PRACTICAL ELECTRONICS

www.epemag.com

WIN A MICROCHIP CAN Development Kit

MULTI-FUNCTION ACTIVE FILTER MODULE

- Can be configured as a low-pass, high-pass or bandpass filter
- Ideal for use as an active crossover in loudspeaker systems
- Total harmonic distortion typically 0.003%
- Filter attenuation of 80dB per decade

LOOP ANTENNA AND AMPLIFIER

Perfect for long-distance AM radio reception

METAL LOCATOR

Ideal for finding nails, steel frames, studs and bracing in plaster walls

BEAM-BREAK FLASH TRIGGER

Trigger a delay unit/photoflash by interrupting an IR light

PLUS

TEACH-IN 2011 – PART 9

A not-to-be-missed introduction to analogue-to-digital and digital-to-analogue conversion

$8.99US £4.25UK
JULY 2011 PRINTED IN THE UK
07
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Low-Power Microcontrollers for Battery-Friendly Design

Microchip Offers Lowest Currents for Active and Sleep Modes

Extend the battery life in your application using PIC® microcontrollers with nanoWatt XLP Technology and get the industry's lowest currents for Active and Sleep modes.

Microchip's new peripheral-rich PIC12F182X, PIC16F182X and PIC16F19XX families offer active currents of less than 50 µA and sleep currents down to 20 nA. These products enable you to create battery-friendly designs that also incorporate capacitive touch sensing, LCD, communications and other functions which help differentiate your products in the marketplace.

Microchip's Enhanced Mid-range 8-bit architecture provides up to 50% increased performance and 14 new instructions that result in up to 40% better code execution over previous-generation 8-bit PIC16 MCUs.

PIC12F182X and PIC16F182X families include:

- Packages ranging from 8 to 64 pins
- mTouch™ capacitive touch-sensing
- Multiple communications peripherals
- Dual I²C™/SPI interfaces
- PWM outputs with independent time bases
- Data signal modulator

PIC16F19XX family includes:

- mTouch capacitive touch-sensing
- LCD drive
- Multiple communications peripherals
- More PWM channels, with independent timers
- Up to 28 KB of Flash program memory
- Enhanced data EEPROM
- 32-level bandgap reference
- Three rail-to-rail input comparators

GET STARTED IN 3 EASY STEPS

1. View the Low Power Comparison videos
2. Download the Low Power Tips 'n Tricks
3. Order samples and development tools
   www.microchip.com/XLP

PIC16F193X 'F1' Evaluation Platform - DM164130-1

Intelligent Electronics start with Microchip

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www.microchip.com/xlp

MICROCHIP

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● PROJECTS ● THEORY ●
● NEWS ● COMMENT ●
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VOL. 40. No 7 July 2011

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INCORPORATING ELECTRONICS TODAY INTERNATIONAL

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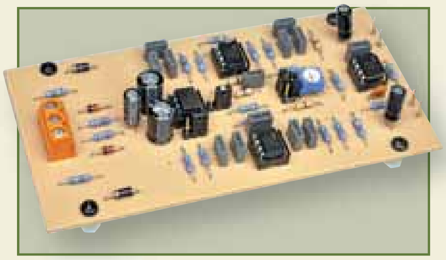
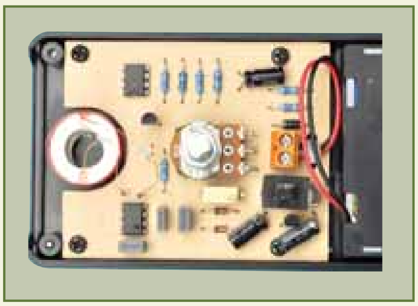
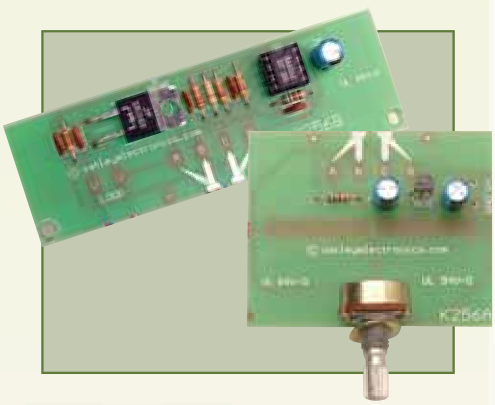
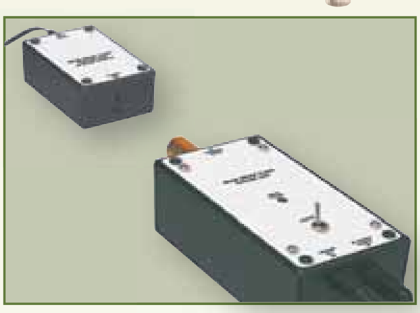








Projects and Circuits

Series and Features

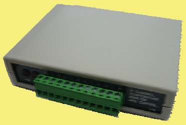
Regulars and Services

Our August 2011 issue will be published on Thursday 14 July 2011, see page 80 for details.

Hot New Products!

Here are a few of the most recent products added to our range. See website or join our email Newsletter for all the latest news.

4-Channel Serial Port Temperature Monitor & Controller Relay Board



4 channel computer serial port temperature monitor and relay controller with four inputs for Dallas DS18S20 or DS18B20 digital thermometer sensors (£3.95 each). Four 5A rated relay channels provide output control. Relays are independent of sensor channels, allowing flexibility to setup the linkage in any way you choose. Commands for reading temperature and relay control sent via the RS232 interface using simple text strings. Control using a simple terminal / comms program (Windows HyperTerminal) or our free Windows application software.
Kit Order Code: 3190KT - **£84.95**
Assembled Order Code: AS3190 - **£99.95**

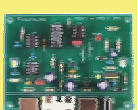
40 Second Message Recorder

Feature packed non-volatile 40 second multi-message sound recorder module using a high quality Winbond sound recorder IC. Standalone operation using just six onboard buttons or use onboard SPI interface. Record using built-in microphone or external line in. 8-24 Vdc operation. Just change one resistor for different recording duration/sound quality. sampling frequency 4-12 kHz.
Kit Order Code: 3188KT - **£29.95**
Assembled Order Code: AS3188 - **£37.95**
120 second version also available

Bipolar Stepper Motor Chopper Driver

Get better performance from your stepper motors with this dual full bridge motor driver based on SGS Thompson chips L297 & L298. Motor current for each phase set using on-board potentiometer. Rated to handle motor winding currents up to 2 Amps per phase. Operates on 9-36Vdc supply voltage. Provides all basic motor controls including full or half stepping of bipolar steppers and direction control. Allows multiple driver synchronisation. Perfect for desktop CNC applications.
Kit Order Code: 3187KT - **£39.95**
Assembled Order Code: AS3187 - **£49.95**

Video Signal Cleaner



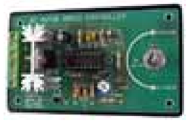
Digitally cleans the video signal and removes unwanted distortion in video signal. In addition it stabilises picture quality and luminance fluctuations. You will also benefit from improved picture quality on LCD monitors or projectors.
Kit Order Code: K8036KT - **£32.95**
Assembled Order Code: VM106 - **£49.95**

Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix).

Motor Speed Controllers

Here are just a few of our controller and driver modules for AC, DC, Unipolar/Bipolar stepper motors and servo motors. See website for full details.

DC Motor Speed Controller (100V/7.5A)

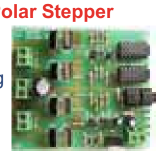


Control the speed of almost any common DC motor rated up to 100V/7.5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied. Dimensions (mm): 60Wx100Lx60H.
Kit Order Code: 3067KT - **£19.95**
Assembled Order Code: AS3067 - **£27.95**

Computer Controlled / Standalone Unipolar Stepper Motor Driver

Drives any 5-35Vdc 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps. Provides speed and direction control. Operates in stand-alone or PC-controlled mode for CNC use. Connect up to six 3179 driver boards to a single parallel port. Board supply: 9Vdc. PCB: 80x50mm.
Kit Order Code: 3179KT - **£16.95**
Assembled Order Code: AS3179 - **£23.95**

Computer Controlled Bi-Polar Stepper Motor Driver



Drive any 5-50Vdc, 5 Amp bi-polar stepper motor using externally supplied 5V levels for STEP and DIRECTION control. Opto-isolated inputs make it ideal for CNC applications using a PC running suitable software. Board supply: 8-30Vdc. PCB: 75x85mm.
Kit Order Code: 3158KT - **£24.95**
Assembled Order Code: AS3158 - **£34.95**

Bidirectional DC Motor Speed Controller

Control the speed of most common DC motors (rated up to 32Vdc/10A) in both the forward and reverse direction. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections.
Kit Order Code: 3166v2KT - **£23.95**
Assembled Order Code: AS3166v2 - **£33.95**

AC Motor Speed Controller (600W)

Reliable and simple to install project that allows you to adjust the speed of an electric drill or 230V AC single phase induction motor rated up to 600 Watts. Simply turn the potentiometer to adjust the motors RPM. PCB: 48x65mm. Not suitable for use with brushless AC motors.
Kit Order Code: 1074KT - **£15.95**
Assembled Order Code: AS1074 - **£23.95**

See www.quasarelectronics.com for lots more motor controllers

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Order Code EPL500 - **£199.95**
Also available: 30-in-1 **£19.95**, 50-in-1 **£29.95**, 75-in-1 **£39.95** £130-in-1 **£49.95** & 300-in-1 **£89.95** (see website for details)

Tools & Test Equipment

We stock an extensive range of soldering tools, test equipment, power supplies, inverters & much more - please visit website to see our full range of products.

Advanced Personal Scope 2 x 240MS/s

Features 2 input channels - high contrast LCD with white backlight - full auto set-up for volt/div and time/div - recorder roll mode, up to 170h per screen - trigger mode: run - normal - once - roll ... - adjustable trigger level and slope and much more.
Order Code: APS230 - ~~£499.95~~ **£399.95**

Personal Scope 10MS/s

The Personal Scope is not a graphical multimeter but a complete portable oscilloscope at the size and the cost of a good multimeter. Its high sensitivity - down to 0.1mV/div - and extended scope functions make this unit ideal for hobby, service, automotive and development purposes. Because of its exceptional value for money, the Personal Scope is well suited for educational use.
Order Code: HPS10 - ~~£189.95~~ **£159.95**
See website for more super deals!

No.1 FOR KITS

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Sight & Sound Kits for Electronic Enthusiasts

KIT OF THE MONTH

Hearing Loop Receiver Kit

KC-5497 £12.75 plus postage & packing

A hearing loop is an inductive assisted listening system for the hearing impaired. They're typically installed in venues such as churches and conference rooms to enable listeners to receive in-ear communication via a wireless induction loop. You can now install this technology on your own TV, home theatre or hi-fi system. This will enable someone who's hard of hearing to hear at their own volume level without having to turn the volume up to a level too high for everyone else. The receiver will drive a pair of headphone or earbuds from the signal picked up from the hearing loop. The whole unit is completely self-contained and can be carried around in a pocket or you can add your own belt clip, so the user isn't constrained by a set of headphone leads. The kit is complete with case, label, PCB and components.

- Current consumption: 10mA
- Frequency response: 100Hz - 5kHz
- S/N ratio: 67dB
- Battery voltage indication: Down to 7V
- PCB: 65 x 86mm

Note: Transmitter not included

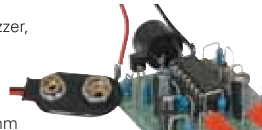
Improve Your Hearing Without The EXPENSE!

Clifford The Cricket

KC-5178 £6.25 plus postage & packing

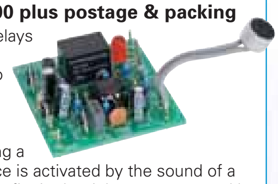
Clifford hides in the dark and chirps annoyingly until a light is turned on - just like a real cricket. Clifford is created on a small PCB, measuring just 40 x 35mm and has cute little LED insect eyes that flash as it sings. Just like a real cricket, it waits a few seconds after darkness until it begins chirping, and stops instantly when a light comes back on.

- PCB, piezo buzzer, LDR plus all electronic components supplied
- PCB: 41 x 36mm



"Minivox" Voice Operated Relay

KC-5172 £6.00 plus postage & packing



Voice operated relays are used for 'hands free' radio communications and some PA applications etc. Instead of pushing a button, this device is activated by the sound of a voice. This tiny kit fits in the tightest spaces and has almost no turn-on delay. 12VDC @ 35mA required. Kit is supplied with PCB electret mic, and all specified components.

- PCB: 47 x 44mm

Communicate Hands Free!

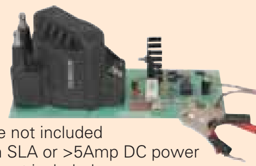
SCI-FI Kits

Jacob's Ladder High Voltage Display Kit MK2

KC-5445 £15.75 plus postage & packing

With this kit and the purchase of a 12V ignition coil (available from auto stores and parts recyclers), create an awesome rising ladder of noisy sparks that emits the distinct smell of ozone. This improved circuit is suited to modern high power ignition coils and will deliver a spectacular visual display.

Kit includes PCB, pre-cut wire/ladder and all electronic components.



- 12V automotive ignition coil and case not included
- 12V car battery, 7Ah SLA or >5Amp DC power supply required and not included
- PCB: 170 x 76mm

Warning: The Jacobs Ladder Kit uses potentially dangerous voltage.

Theremin Synthesiser Kit MkII

KC-5475 £27.25 plus postage & packing

The ever-popular Theremin is better than ever! From piercing shrieks to menacing growls, create your own eerie science fiction sound effects by simply moving your hand near the antenna. It's now easier to build with PCB-mounted switches and pots to reduce wiring to just the hand plate, speaker and antenna and has the addition of a skew control to vary the audio tone from distorted to clean.

MORE INFO AVAILABLE ONLINE

- Complete kit contains PCB with overlay, pre-machined case and all specified components
- PCB: 85 x 145mm

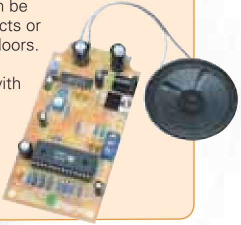
Don't just sit there BUILD SOMETHING!

Starship Enterprise Door Sound Emulator

KC-5423 £14.50 plus postage & packing

This easy to build kit emulates the unique sound of a cabin door opening or closing on the Starship Enterprise. The sound can be triggered by switch contacts or even fitted to automatic doors.

- Kit supplied with PCB with overlay, speaker, case and all specified components
- 9-12VDC regulated
- PCB: 84 x 148mm

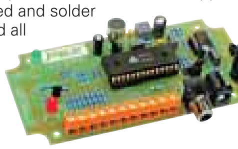


45 Second Voice Recorder Module

KC-5454 £16.00 plus postage & packing

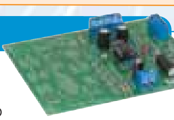
Will record two, four or eight different messages for random-access playback or a single message for "tape mode" playback. It also provides cleaner and glitch-free line-level audio output suitable for feeding an amplifier or PA system. It can be powered from any source of 9 - 12VDC. Supplied with silk screened and solder masked PCB and all electronic components.

- PCB: 58 x 120mm



Bridge Mode Adaptor

KC-5469 £10.25 plus postage & packing



Enables you to run a stereo amplifier in 'Bridged Mode' to effectively double the power available to drive a single speaker. There are no modifications required on the amplifier and the signal processing is done by this clever kit. Supplied with silk screened PCB and components. Requires balanced (+/-) 15-60V power supply.

- PCB: 103 x 85mm

Audio Kits

Studio 350 - High Power Amplifier

KC-5372 £63.50 plus postage & packing

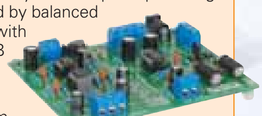
The studio 350 power amplifier will deliver a whopping 350WRMS into 4 ohms or 200WRMS into 8 ohms. It offers real grunt using a high power MJ21193/4 transistor and is super quiet with a very low signal to noise ratio and harmonic distortion. This kit is supplied in short form with PCB and electronic components. Kit requires heatsink and (+/-) 70V power supply as described in instructions. See website for more specifications.

- PCB: 136 x 241mm

Balanced to Unbalanced Audio Converter

KC-5468 £12.00 plus postage & packing

This kit will adapt an unbalanced input to balanced output and vice versa and allows domestic equipment to be integrated into a professional installation while maintaining the inherent high immunity to noise pick-up on long cable runs provided by balanced lines. Kit supplied with solder masked PCB and all specified components.



- PCB: 85 x 103mm

Flickering Flame Lighting

KC-5234 £6.25 plus postage & packing

This lighting effect uses a single 20 watt halogen lamp (the same as those used for domestic down lights) to mimic its' namesake. Mounted on a compact PCB, it operates from 12VDC and uses just a handful of readily available components. Use it for stage performances or for unique lighting effects at home.

- Kit includes 20W halogen lamp
- PCB plus electronic components
- Includes ceramic base for halogen lamp
- PCB: 38 x 58mm

Post & Packing Charges

Order Value	Cost
£10 - £49.99	£5
£50 - £99.99	£10
£100 - £199.99	£20
£200 - £499.99	£30
£500+	£40
Max weight 12lb (5kg)	
Heavier parcels POA	
Minimum order £10	

Note: Products are despatched from Australia, so local customs duty & taxes may apply.

- **All pricing in Pounds Sterling**
- **Minimum order £10**

Prices valid until 31/7/2011

HOW TO ORDER

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Now Available - Cebek Modules
All modules assembled & tested.
Digital Echo Chamber Kit
A compact sound effects kit, with built-in mic or line in, line out or speaker (500mW). 4 Adjustment controls
Power: 9Vdc 150mA
MK182 Velleman kit £11.43
Digital Record/Player
Non volatile flash memory, Single 20 sec recording via integral mic, 2W output to 8Ω speaker.
Power: 5Vdc 100mA
C-9701 Cebek Module £7.89
3rd Brake Light Flasher Kit
Works with any incandescent or LED rear centre brake light. Flashes at 7Hz for 5 or 10 times, adjustable re-triggering.
Power: 12Vdc max load 4A
MK178 Velleman kit £6.30
Multifunction Up/Down Counter
An up or down counter via on-board button or ext input. Time display feature. Alarm count output. 0-9999 display.
Power: 9-12Vdc 150mA
K8035 Velleman kit £17.85
2 Digital Counter
Standard counter, 0 to 99 from input pulses or external signal. With reset input, 13.5mm Displays,
Power: 12Vdc 90mA.
CD-9 Cebek Module £12.99
Digital Clock Mini Kit
Red 7 Segment display in attractive enclosure, automatic time base selection, battery back-up, 12 or 24Hr modes.
Power: 9Vac or dc
MK151 Velleman kit £15.09
Nixie Clock Kit
Gas filled nixie tubes with their distinctive orange glow. HH:MM display, automatic power sync 50/60Hz
Power: 9-12Vac 300mA
K8099 Velleman kit £64.96
1.8W Mono Amplifier
Compact mono 1.8W RMS 4Ω power stage, short circuit & reverse polarity protection. 30-18kHz, Power: 4-14Vdc 150mA
E-1 Cebek Module £5.87
Proximity Card Reader Kit
A simple security kit with many applications. RFID technology activates a relay, either on/off or timed. Supplied with 2 cards, can be used with up to 25 cards. Power: 9Vac or dc
MK179 Velleman kit £14.25
Mini USB Interface Board
New from Velleman this little interface module with 15 inputs/outputs inc digital & analogue in, PWM outputs. USB Powered 50mA, Software supplied
VM167 Module £26.80
20W 2 Channel Amplifier
Mono amplifier with 2 channels (Low & High frequecy), 20W RMS 4Ω per channel, adjustable high level. 22-22kHz, short circuit & reverse polarity protection.
Power: 8-18Vdc 2A
E-14 Cebek Module £22.11
Running Microbug Kit
Powered by two subminiature motors, this robot will run towards any light source. Novel shape PCB with LED eyes.
Power: 2 x AAA Batteries
MK127 Velleman kit £9.02
Thermostat Mini Kit
General purpose low cost thermostat kit. +5 to +30°C Easily modified temperature range/min/max/hysteresis 3A Relay
Power: 12Vdc 100mA
MK138 Velleman Kit £4.55
5W Stereo Amplifier
Stereo power stage with 5W RMS 4Ω, 30-18kHz, short circuit & reverse polarity protection.
Power: 6-15Vdc 500mA
ES-2 Cebek Module £21.54
200W Power Amplifier
A high quality audio power amp, 200w music power @ 4Ω 3-200kHz Available as a kit without heatsink or module including heatsink.
K8060 Velleman kit £12.85
Heatsink for kit £9.95
VM100 Module £38.54
Velleman Function Generator
PC Based USB controlled function generator. 0.01Hz to 2Mhz Pre-defined & waveform editor. Software supplied. See web site for full feature list.
PCGU1000 Velleman £118.38
12Vdc Power Supply
Single rail regulated power supply complete with transformer. 130mA max, low ripple, 12Vdc with adjustment.
FE-103 Cebek Module £13.16
MP3 Player Kit
Plays MP3 files from an SD card, supports ID3 tag which can be displayed on optional LCD. Line & headphone output. Remote control add-on. Power: 12Vdc 100mA
K8095 Velleman kit £39.99
Velleman PC Scope
PC Based USB controlled 2 channel 60Mhz oscilloscope with spectrum analyser & Transient recorder. 2 Scope probes & software included. See web site for full feature list.
PCSU1000 Velleman £249.00
1-180 Second Timer
Universal timer with relay output. Time start upon power up or push button. LED indication. 5A Relay
Power: 12Vdc 60mA
I-1 Cebek Module £12.92
DC to Pulse width Modulator
A handy kit to accurately control DC motors etc. Overload & short circuit protection. Input voltage 2.5-35Vdc, Max output 6.5A.
Power: 8-35Vdc
K8004 Velleman kit £9.95
Velleman PC Scope/Generator
PC Based USB controlled 2 channel oscilloscope AND Function generator. Software included. See web site for full feature list.
PCSGU250 Velleman £113.67
Cyclic Timer
Universal timer with relay output. Time start upon power up or push button. On & Off times 0.3-60 Seconds, LED indication. 5A Relay
Power: 12Vdc 80mA
I-10 Cebek Module £14.12
Audio Analyser Kit
A small spectrum analyser with LCD. Suitable for use on 2, 4 or 8Ω systems. 300mW to 1200W(2Ω) 20-20kHz Panel mounting, back-lit display. Power: 12Vdc 75mA
K8098 Velleman kit £31.65
RF Remote Control Transmitter
Single channel RF keyfob transmitter with over 13,122 combinations. Certified radio frequency 433.92MHz.
Power: 12Vdc 2mA (inc) For use with TL-1,2,3,4 receivers.
TL-5 Cebek Module £14.64
Light Detector
Adjustable light sensor operating a relay. Remote sensor & terminals for remote adjustment pot. 5A Relay
Power: 12Vdc 60mA
I-4 Cebek Module £13.98
USB
USB DMX Interface
512 DMX Channels controlled by PC via USB. Software & case included. Available as a kit or ready assembled module.
K8062 Velleman kit £47.90
VM116 Module £67.15
RF Remote Control Receiver
Single channel RF receiver with relay output. Auto or manual code setup. Momentary output, 3A relay
Power: 12Vdc 60mA For use with TL-5 or TL-6 transmitters.
TL-1 Cebek Module £28.25
Liquid Level Detector
A liquid level operated relay. Remote sensor operates relay when in contact with a liquid. 5A Relay
Power: 12Vdc 60mA
I-6 Cebek Module £13.08
USB Interface Board
USB
Featuring 5 in, 8 digital outputs, 2 in & 2 analogue outputs. Supplied with software. Available as a kit or ready assembled module.
K8055 Velleman kit £24.80
VM110 Module £34.90
Keypad Access Control
An electronic lock with up to ten 4 digit codes. Momentary or timed (1-60ec/1-60min) output. Relay 5A
Power: 12Vdc 100mA Keypad included.
DA-03 Cebek Module £54.26
Thermostat
A temerature controlled relay. Adjustable between -10 to 60°C Sensor on remote PCB. Connector for external adjustment pot. 5A Relay
Power: 12Vdc 60mA
I-8 Cebek Module £12.80
8 Channel USB Relay Board
PC Controlled 16A relays with toggle, momentary or timed action. Test buttons included, available in a kit or assembled.
K8090 Velleman kit £39.95
VM8090 Module £58.40
AC Motor Controller
A 230Vac 375W motor speed control unit giving 33 to 98% of full power.
Power: 230Vac
R-8 Cebek Module £12.14
Start / Stop Relay
Simple push button control of a relay. Either 1 or 2 button operation 5A Relay
Power: 12Vdc 60mA
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VOL. 40 No. 7 JULY 2011

EVERYDAY PRACTICAL ELECTRONICS

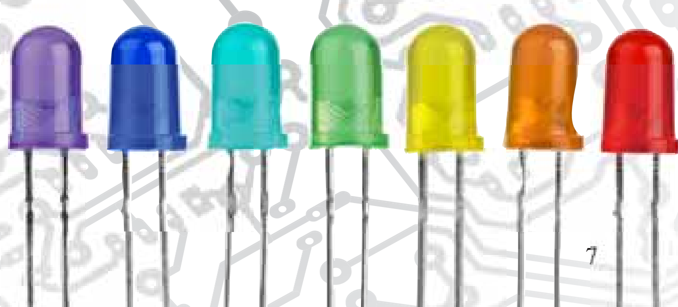
Computing for the 'common man'

An electronics celebrity came to town last month (town being Brighton for me) – a certain Steve from Apple attended a conference by the seaside. There was a time when the name 'Steve', in relation to Apple, meant two people. Of course one of them was (and still is) Steve Jobs, who has become one of the most famous people in the world of electronics and information technology. Apple, the company he co-founded, is the richest technology corporation in the world; the Apple brand is the world's most valuable; and Jobs was voted CEO of the decade by Fortune magazine in 2009. One of the ironies of this achievement is that Steve Jobs is not an engineer. He would be the first to admit that he hasn't 'engineered' any of their products, but what he does have is a crystal clear vision of what he wants to produce and how to achieve it.

The very first Apple product Jobs launched was the 'Apple 1' computer in 1976. However, it was designed and built by the other Steve, Steve Wozniak. Between them, the two Steves went on to lay the foundations of the modern Apple company. Although Wozniak left Apple in 1987, without his input and foresight about what a PC should be, it is doubtful that Apple could have got off the ground and computers would look very different today. I doubt if we'd still be stuck in the 'command line prompt' world of MS-DOS, but a big part of Microsoft's initial impetus for moving to Windows came from the success of Apple's early graphical user interface.

Although never one for the limelight, engineer Steve is still an important figure in the history of PCs, so it is worth following his views on what the future holds for computing. One thing he has always been passionate about is spreading the use of computers for everyone. The earliest PCs were little more than kits of parts and a PCB. If you were lucky you got an assembled motherboard, but no case, no monitor and certainly no hard drive (programs were stored and loaded using compact cassette tapes). Things changed quickly and complete systems – at a price – were soon available, but you needed a fair amount of knowledge and perseverance to become PC literate.

Contrast that with today, where modern systems easily play music and films, search the Internet, and a whole host of other activities. What is surprising though, is how similar many modern computers look to models 25 or more years old – a box, attached to a display, keyboard and mouse. Now, however, there is a completely new format in the shape of tablet computers, the most famous being the iPad from Apple. And what does pioneer Wozniak think of them? A quote from him caught my eye recently; speaking to engineers at a conference in California, he said: 'The tablet is not necessarily for the people in this room. It's for the normal people in the world.' Which is exactly the product both Steves set out to make 35 years ago.



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NEWS

A roundup of the latest Everyday News from the world of electronics

3D video on demand by Barry Fox

The annual European press conference held to promote the *IFA Electronics Show* was again enlivened by the now traditional slanging match between the organisers of the September IFA show in Berlin and the January *CES* event in Las Vegas. But, also by tradition, the two shows never refer to each other by name.

'If there is one single piece of information I want you to take away from this event, it is that IFA is the number one show for the trade and media,' Dr Christian Göke, CEO Messe Berlin told 300 journalists flown in from around the world to sunny Alicante, Spain.

'Anyone who has already got that message is free to leave the room and go to the pool. But if you would like to stay, I will give good reasons why IFA is global number one, and the *only* place in the world for so many international retailers and media.'

'We are number one in the world with stable and positive growth. This sets us apart from all other shows in the world.'

Several manufacturers were given 20-minute slots to promote their electronic wares. Michael Zoller, Samsung's European marketing director was clearly under orders from his Korean bosses to try and cool the bitter dispute over active-shutter versus passive-polarising 3DTV – while promoting Samsung's continuing commitment to active shutter in the face of rival LG's high profile criticism of active shuttering.

This came as Toshiba followed Philips and quietly slid passive TV sets into its new TV range, to sell alongside the company's existing active shutter sets.

This summer, Samsung will launch a free 3D video on demand service, delivered direct by broadband to Samsung active shutter Internet TV sets. 3D clips, trailers and ten Imax Theatre 3D movies – each of 45 minutes length and as currently available on Blu-ray discs – will stream for free.

To boost 3D sales, Samsung will start selling packs of two pairs of active shutter glasses, for 79 euros (approx £67). These glasses will use an RF connection, working on the 2.4GHz Bluetooth frequency and using pairing technology similar to, but not to quite the same standard, as Bluetooth. The glasses need only be push-button paired once with the TV, and then remain paired.

Using RF avoids the problem of interference, which has plagued infrared active shutter connection, particularly in stores where retailers want to demonstrate several 3DTV sets and different brands in close proximity. The IR signals for one set can stop other sets' glasses working.

Zoller confirmed that all 2011 Samsung 3DTVs will use RF Bluetooth-style connection, and there is no compatibility between 2011 glasses and 2010 infrared sets.

'We are now 100% Bluetooth. Infrared is finished', he said.

However, Samsung pledges to keep selling IR glasses for owners of existing 3D sets.

Arduino-compatible 32-bit microcontroller development platform

Microchip has launched the first 32-bit-microcontroller-based, open-source development platform that is compatible with Arduino hardware and software. Designed and manufactured by Digilent, a Microchip authorised design partner, the chipKIT platform is a 32-bit Arduino solution to enable hobbyists and academics to easily, and inexpensively, integrate electronics into their projects, even if they do not have an electronic-engineering background.

The boards' starting price is $26.95 each. The platform consists of two PIC32-based development boards and open-source software that is fully compatible with the Arduino programming language and development environment. The chipKIT hardware is compatible with existing Arduino shields and applications, and can be developed using the Arduino IDE and existing resources, such as code examples, libraries, references and tutorials. The easy-to-use kit supports project development in many disciplines, such as mechanical engineering, computer science and even art.

The PIC32-based chipKIT boards enable 80MHz performance, and provide up to 512KB Flash, with up to 128KB RAM. They feature connectivity peripherals, including Ethernet, CAN, and USB (Full-Speed Host, Device and OTG), plus peripherals such as

multiple timers, a 16-channel 1 MSPS Analogue-to-Digital Converter (ADC), two comparators, and multiple I2C, SPI, and UART interfaces. The chipKIT integrates Microchip's PIC32 microcontroller which is the highest performance 32-bit microcontroller in its class.

A ChipKIT video demo is available at: **www.microchip.com/get/D268**

WORLD RECORD

Researchers at the Karlsruhe Institute of Technology (KIT) have succeeded in encoding data at a rate of 26 terabits per second (26,000 billion bits per second) on a single laser beam, transmitting them over a distance of 50km, and decoding them successfully. This is the largest data volume ever transported on a laser beam. The process developed by KIT allows the contents of 700 DVDs to be transmitted in just one second.

With this experiment, the KIT scientists in the team of Professor Jürg Leuthold beat their own record in high-speed data transmission of 2010, when they exceeded the 10 TB/s barrier.

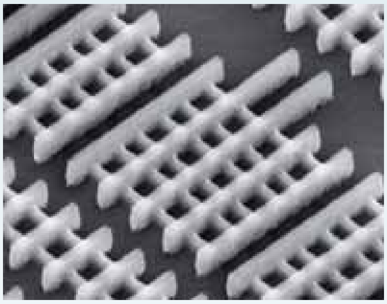
'Our result shows that physical limits have not yet been exceeded, even at very high data rates', Leuthold says.

'A few years ago, data rates of 26 terabits per second were deemed Utopian, even for systems with many lasers… and there would not have been many applications. With 26 terabits per second, it would have been possible to transmit up to 400 million telephone calls at the same time. Nobody needed this at that time. Today, the situation is different. Video transmissions predominate on the Internet and require extremely high bit rates.

Companies and scientists from all over Europe were involved in the experimental implementation of ultra-rapid data transmission at KIT. Among them were members of the University of Southampton.

Revolutionary 3D Transistor

Intel has announced a significant breakthrough in the evolution of the transistor, the building block of modern electronics. For the first time since the invention of silicon transistors over 50 years ago, transistors using a three-dimensional structure will be put into high-volume manufacturing. Intel will introduce a revolutionary 3D transistor design called 'Tri-Gate', first disclosed by Intel in 2002, into high-volume manufacturing at the 22nm level.



Intel's 22nm 3D Tri-Gate Transistor

The three-dimensional Tri-Gate transistors represent a fundamental departure from the two-dimensional planar transistor structure that has powered not only all computers, mobile phones and consumer electronics to date, but also the electronic controls within cars, spacecraft, household appliances, medical devices and thousands of other everyday devices for decades.

Tri-Gate transistors enable chips to operate at lower voltage with lower leakage, providing an unprecedented combination of improved performance and energy efficiency compared to previous state-of-the-art transistors. The capabilities give chip designers the flexibility to choose transistors targeted for low power or high performance, depending on the application.

These new transistors provide up to 37% performance increase at low voltage versus Intel's 32nm planar transistors. This gain means that they are ideal for use in small handheld devices, which operate using less energy to 'switch' – less than half the power when at the same performance level as 2D planar transistors on 32nm chips.

New evaluation kit for Sensirion's differential pressure sensors

EK-P3 is an evaluation kit from Swiss CMOS-based sensor manufacturer Sensirion. It is a straightforward and cost-effective option for testing their digital differential pressure sensors.

The set consists of a USB stick that is connected to the SDP610 sensor by an adapter cable. Software available online enables a PC to display the data or save it to a spreadsheet. The sensors have a digital (I2C) output signal and provide excellent accuracy and sensitivity. For more information, see: **www.sensirion.com/ekp3**

Competition time!

A couple of competitions that will be of interest to *EPE* readers who have a creative streak...

Picture Bletchley Park

Bletchley Park, Milton Keynes, once a top-secret institution where all photography was banned, is now welcoming photographers with open arms to take part in its inaugural 'Picture Bletchley Park' photographic competition.

The prestigious board of judges includes Kate Day, communities editor for **telegraph.co.uk**, who is also well known for her blogs about photography and Damien Demolder, editor of the magazine, *Amateur Photographer*.

The competition is open to everyone, regardless of experience. Participants may submit photographs of any aspect of Bletchley Park, from the buildings and the army of staff and volunteers who work there, to its priceless historic collections and lovely gardens.

The winners will feature in Bletchley Park's official 2012 calendar, with the photograph by the overall winner featuring on the front cover. The 13 winning entries, along with 25 runners up, will also be displayed at Bletchley Park during the 'Picture This' event on 2 October, where the winners will each be presented with a framed copy of their entry.

To enter, or for more information and rules, go to: **www.bparkcomp.org.uk.**

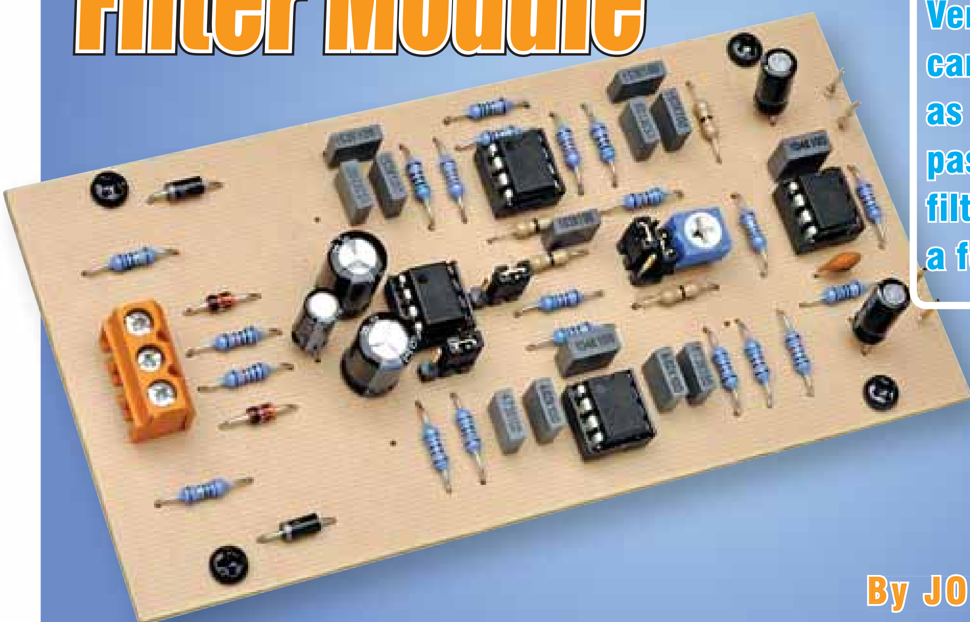
Pylon design competition

Love them or hate them, the great British pylon is an unmistakable part of the landscape. The current 'iconic' design is essentially 80 years old and has been a constant since the birth of the national grid.

Make your mark by redesigning the pylon!

If you fancy a change from designing amplifiers or PIC projects then why not enter the 'Pylon design competition' run by RIBA? (**www.ribapylondesign.com)** It's an opportunity to get involved with enormous currents and voltages by designing a new generation of pylons. Potential pylon aficionados can gain inspiration from Flash Bristow's pylon-themed website at: **www.gorge.org/pylons**, and if you are really keen then why not join the Pylon Appreciation Society at: **www.pylons.org**.

Multi-Function Active Filter Module



Versatile design – can be configured as a low-pass, high-pass or bandpass filter just by moving a few jumper links

By JOHN CLARKE

This versatile Active Filter is ideal for use as an active crossover in loudspeaker systems, but has lots of other uses as well. It can be configured as a low-pass filter (for driving sub-woofer amplifiers), as a high-pass filter or as a bandpass filter, simply by moving a few on-board jumper links.

ACTIVE filters are used in many analogue circuits to tailor the frequency response. For example, an active filter could be used to prevent signals below 20Hz from passing through to the next stage (eg, to an amplifier). In this case, the filter allows the higher audio frequencies to pass through, but blocks the sub-audio signals (including DC).

This type of filter is called a 'high-pass' (HP) filter. If an HP filter is incorporated into an audio amplifier, it will prevent the woofer in a loudspeaker system from being driven at very low frequencies. In fact, it could be used as a turntable rumble filter to follow a magnetic cartridge preamplifier.

Preventing a loudspeaker from being driven at very low frequencies is important because such frequencies would cause audible distortion in the sound due to excessive cone movement. In addition, excessive cone movement at or below the loudspeaker's resonance frequency could damage the loudspeaker.

Similarly, an active filter could also be used to limit signals above 20kHz. This will prevent supersonic signals from driving the loudspeaker and protect the tweeter(s) from damage. This type of filter is called a low-pass (LP) filter; it allows frequencies below a certain frequency to pass through, but blocks higher frequencies.

Bandpass filter

Cascading a high-pass filter and a low-pass filter produces a bandpass filter. So, if a 20Hz high-pass filter and a 20kHz low-pass filter are cascaded, we end up with a bandpass ranging from 20Hz to 20kHz. This means that the signal is attenuated both below 20Hz and above 20kHz, while those frequencies between 20Hz and 20kHz are basically left unattenuated.

However, some attenuation (or reduction in level) does occur as the signal frequency approaches 20Hz and 20kHz, ie, near the so-called corner or 'roll-off' frequencies.

Additional filters can also be used to split the 20Hz to 20kHz audio

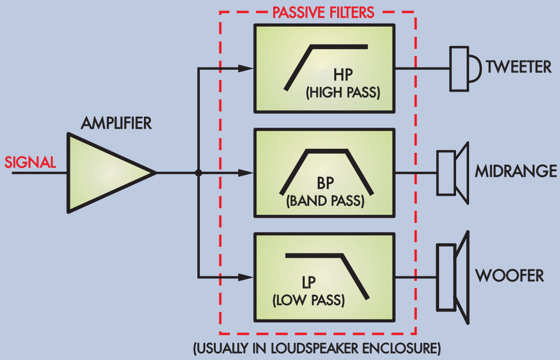


Fig.1: a single power amplifier is usually used to drive a passive crossover network in a loudspeaker box.

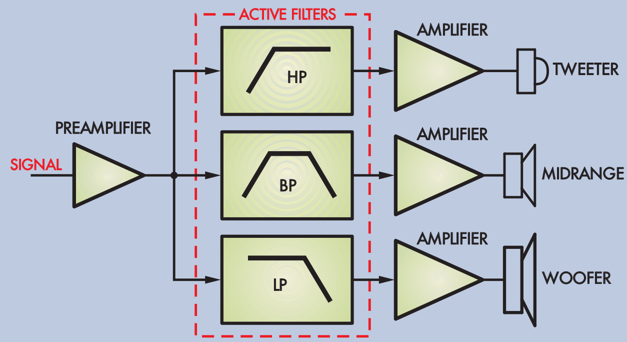


Fig.2: the arrangement for an active crossover filter system. The filters go before the power amplifiers and a separate amplifier is required for each loudspeaker driver.

frequency range into separate frequency ranges or bands. This might be done to produce a 2-way or 3-way active crossover for two or three drivers in a loudspeaker system.

In greater detail, many loudspeaker systems include woofer, midrange and tweeter drivers in the same box – see Fig.1. This is called a 3-way system, while a 2-way system includes just a woofer and a tweeter.

The separate drivers are used because no single driver can faithfully reproduce the whole audible range from 20Hz to 20kHz. So the audio band of frequencies is divided up and each driver is fed with its own 'ideal' range of frequencies. In a 3-way system, for example, the woofer could be provided with signals ranging from 20Hz to say 150Hz, while the midrange would handle signals ranging from 150Hz to 2kHz. The tweeter would then cover the remainder of the audio range, ie, from 2kHz to 20kHz.

Passive crossovers

In most loudspeaker systems, the incoming audio signal is divided into separate frequency bands using passive filters. These 'crossover filters' are located inside the loudspeaker box itself, and are made up using inductors, capacitors and resistors.

A well-designed crossover network gives outputs to match the particular drivers used. This ensures that each driver (ie, woofer, midrange and tweeter) is fed only with a frequency band it can effectively reproduce. In addition, the design must cater for drivers that have different sensitivities and set the signal levels to achieve an overall flat frequency response.

For example, the woofer is often less sensitive than the midrange driver and tweeter, and so the signals to the latter drivers must be reduced so that the output levels from the three drivers are well matched. This does waste amplifier power, however.

Another problem to contend with is non-linearity in the driver impedances. Extra components are often used in the crossover network to correct this, so that the filter appears to drive a purely resistive load. As a result, the crossover networks in high-performance speaker systems are often complex and can be difficult to design and optimise.

They also interpose a complex *RLC* network between the amplifier and the speakers, which can mean a loss of damping factor. This particularly affects the lower frequencies, where a high damping factor is most needed to achieve tight, clean bass and midrange reproduction.

As shown in Fig.1, a single power amplifier usually drives the passive crossover network in a loudspeaker system. However, some loudspeaker systems provide additional connections so that each driver can either be driven independently by its own amplifier (via its passive filter) or by a single amplifier, but with separate wiring to each passive filter section.

Active crossovers

Active crossovers are an alternative to passive filtering. However, for this to work, a separate amplifier is required for each driver – see Fig.2. For a stereo system, that means six (mono) power amplifiers (or three stereo amplifiers) to drive 3-way loudspeakers or four amplifiers for 2-way loudspeakers.

As shown in Fig.2, the crossover filtering is now placed ahead of each amplifier to set the frequency band applied to its driver. There are two advantages to this scheme: (1) better control of the driver and (2) the inductive load presented by the driver does not affect the filter response (as it does in a passive system).

Specifications

Voltage gain: adjustable from 0-2; typically set at 1

Frequency response: filter dependent

Filter attenuation slope: 24dB/octave or 80dB/decade

Total harmonic distortion (THD): typically 0.003% at 1V RMS

Signal-to-noise ratio (SNR): >100dB with respect to 1V input and 22Hz to 22kHz unweighted

Input impedance: 47kΩ

Supply Voltage: ±15V to ± 60V DC dual rail supply, or +12V to 30V DC single rail supply, or 11V to 43V AC

Current Consumption: 40mA maximum

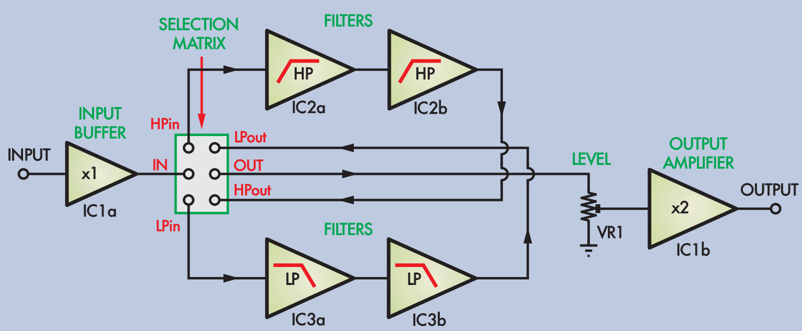


Fig.3: block diagram of the Multi-Function Active Filter. The low-pass and high-pass filter stages each consist of two cascaded op amps. The unit is configured by installing jumper links on the pins of the 'selection matrix'.

So, our Multi-Function Active Filter module is designed to be used ahead of each amplifier. Basically, you need to build and configure one module for each driver (and amplifier) in the system. For a woofer, the module would be configured as a low-pass (LP) filter, while a bandpass (BP) filter would be used ahead of the midrange amplifier. The tweeter driver amplifier would have a high-pass (HP) filter ahead of it.

Supply options

In operation, the Multi-Function Active Filter would typically be powered from the supply rails of the amplifier. Options are available to power the module from supply rails ranging from ±60V down to ±15V, or from an 11V to 43V AC source.

The filter can also be powered from a single supply rail, such as +25V, +15V or +12V. The 12V option enables it to be used in cars.

On-board jumper links are used to configure the module for LP, BP or HP operation. The roll-off frequencies are set by selecting the appropriate resistor and capacitor values in the filter feedback networks. These filter component calculations are made easy by using freely available software from the Internet.

Block diagram

The block diagram of the Multi-Function Active Filter (minus the power supply) is shown in Fig.3. It uses an input buffer stage (IC1a), four op amps to form the filter stages (IC2a, IC2b and IC3a, IC3b) and an output amplifier stage (IC1b)

IC1a is configured with a gain of one and can be connected to drive either the HP or LP filter stages, depending on the jumper options on the 'Selection Matrix' block. If we want an HP filter, then terminal 'IN' is connected to 'HPin' on the matrix block. Alternatively, for an LP filter, 'IN' is connected to terminal 'LPin'.

As shown, the high-pass filter uses two 2-pole HP filters based on IC2a and IC2b. These are connected in series (or 'cascaded'). Similarly, the low-pass filter stage consists of 2-pole LP filters, based on IC3a and IC3b.

The response for an HP filter and the way the filter response is described, is shown in Fig.4a. As indicated, the region where frequencies pass through unattenuated is called the passband. Below the cutoff frequency, the response begins to roll off (or is reduced) in level. This roll-off region is called the stopband.

An LP filter is similar, except that it allows low-frequency signals to pass through, and blocks signals above the cutoff point (Fig.4b). Finally, the bandpass filter rolls off both the low and high-frequency signals, and the pass band is between the high-pass and low-pass cutoff frequencies (Fig.4c).

Roll-off slope

Note that the signal is not fully attenuated at the cutoff points, but instead gradually decreases at a rate determined by the roll-off slope. In this case, each 2-pole filter stage has a roll off of 40dB per decade or 12dB per octave. However, because the filter stages are cascaded, this roll-off increases to 80dB per decade, or 24dB per octave, and the signal level is actually 6dB down at the cutoff (crossover) points.

For a high-pass filter, the output from IC2b is fed through to level control VR1 by connecting point 'HPout' to 'OUT' in the selection matrix. Alternatively, for a low-pass filter, the output of IC3b at 'LPout' is connected to the 'OUT' terminal.

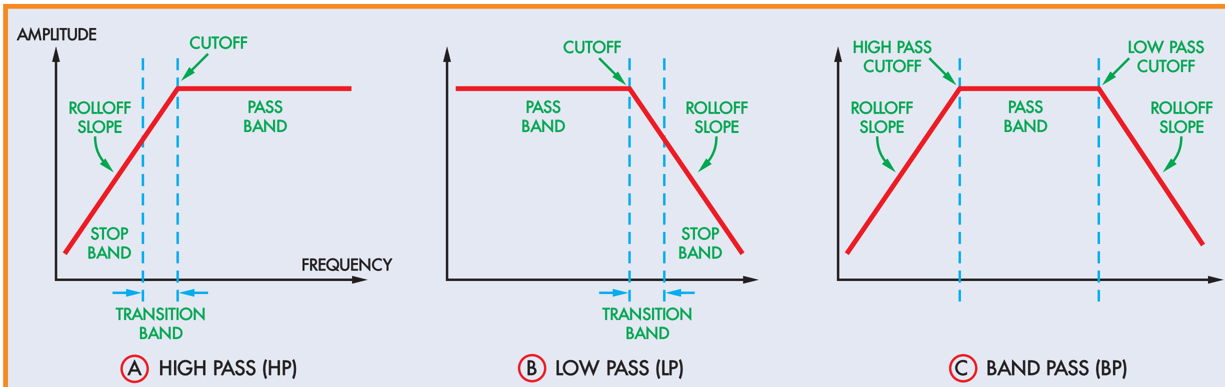
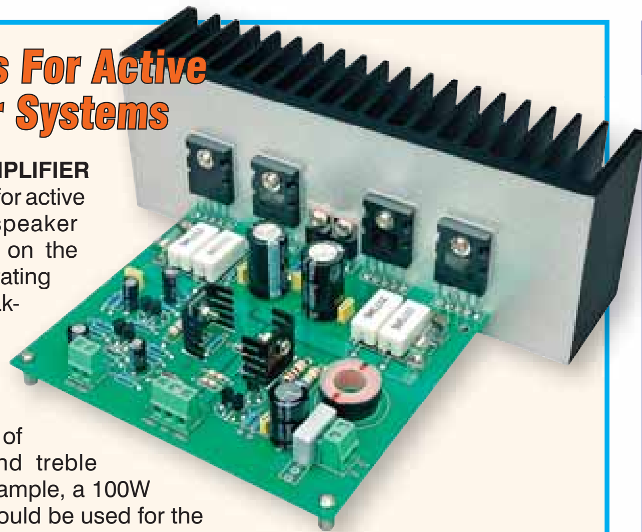


Fig.4: the high-pass filter (A), low-pass filter (B) and bandpass filter (C) response characteristics. Because the op amp filter stages are cascaded, the rolloff slope in each case is 24dB per octave and the signal is actually 6dB down at the cutoff (crossover) points.

Amplifiers For Active Crossover Systems



THE AUDIO AMPLIFIER requirements for active crossover loudspeaker systems depend on the power handling rating for each loudspeaker. Typically, a woofer (or subwoofer) amplifier should have twice the power of the midrange and treble amplifiers. For example, a 100W power amplifier could be used for the woofer, and 50W amplifiers used for the midrange and treble drivers.

One problem is that the output from a preamplifier will only have a single RCA phono output for each left and right channel. However, you will need to connect the preamp signal to two or three active filters, depending on how many drivers are in the loudspeaker.

This problem is easily overcome by using an RCA phono Plug to 2 × RCA phono Socket**,** such as the Jaycar Cat. PA-3560. Two such adaptors will be required for each channel if you want to drive three active filter modules (ie, if you have a 3-way loudspeaker system).

Alternatively, you could use RCA phono plug-to-plug leads, with piggyback RCA phono sockets (eg, Jaycar WA-7090/1/2/3) or you could make up your own 2-way or 3-way phono socket panels.

Parts List

- 1 PC board, code 812, available from the *EPE PCB Service*, size 123mm × 63mm
- 1 UB3-size plastic case, 130mm × 68mm × 44mm (optional)
- 1 3-way PC-mount screw terminal block, 5.08mm pin spacing
- 4 8-pin DIP IC sockets
- 1 3-way DIL pin header, with 2.54mm pin spacings
- 2 3-way SIL pin headers, with 2.54mm pin spacings
- 5 jumper plugs, to suit pin headers
- 1 100mm length of 0.8mm tinned copper wire or four 0Ω links
- 4 PC stakes

Semiconductors
- 3 LM833 dual op amps (IC1 to IC3)
- 1 TL071, LF351 single op amp (IC4)
- 2 1N4744 15V 1W Zener diodes (ZD1,ZD2)
- 2 1N4004 1A 400V diodes (D1,D2)

Capacitors
- 2 470µF 16V PC electrolytic
- 1 100µF 16V PC electrolytic
- 2 4.7µF non-polarised (NP) electrolytic
- 2 100nF MKT polyester
- 1 10nF MKT polyester
- 1 220pF ceramic
- C1,C2,C3 to suit application (use MKT polyester) (see text and tables)

Resistors (0.25W, 1%)

1 47kΩ	2 150Ω
4 10kΩ	3 10Ω

Ra, Rb, R1, R2 and R3 to suit power supply and filter type (use 1% 0.25W for R1, R2 and R3) (see text / tables)

Bandpass filter connections

Bandpass filtering is achieved by cascading the high-pass and low-pass filter stages; ie, by connecting the output of the high-pass stages to the input of the low-pass stages, or vice versa. However, it is normal to feed the signal to an HP filter first, and then use this to drive the LP filter, rather than placing the LP filter first. This will result in less noise due to the final low-pass filtering.

However, you can connect the LP filters first if that's what you want to do.

Normally, to configure a bandpass filter, the signal is first fed to HP filter stage IC2a by linking 'IN' to 'HPin'. The output from IC2b is then fed to the input of low-pass stage IC3a by connecting 'HPout' to 'LPin' in the Selection Matrix. The resulting bandpass filtered signal at the output of IC3b is then fed to VR1 by connecting 'LPout' to 'OUT'.

Level control

The signal on VR1's wiper is fed to IC1b. This is configured as a non-inverting amplifier with a gain of two. As a result, VR1 can be adjusted to vary the signal at its output between zero and x2. This level adjustment allows the sound levels from the woofer, midrange and tweeter drivers to be adjusted when multiple filter modules are used.

By the way, the recommended design for each 2-pole stage is for a Butterworth response. When connected in series, the result of cascading two Butterworth filters is a Linkwitz-Riley (L-R) response.

This is ideal because at the crossover region, where one filter takes over from another, the overall L-R frequency response is flat. Note that the HP and LP filters must be set to the same crossover frequency for this to happen.

As indicated previously, the Multi-Function Active Filter board can only produce a single LP, HP or BP filter output. **This means that it can only provide a signal to one loudspeaker driver – it is not designed to provide two (or more) outputs.**

This in turn means that if you want to separate LP, BP and HP filter outputs, then three filter modules must be built (or six for a stereo system). Basically, a different filter is required for each amplifier, and each can be installed inside its associated amplifier's case.

The inputs of the various active filter modules are then all driven in parallel by the preamplifier.

Circuit details

OK, let's now take a look at the full circuit details – see Fig.7. It comprises

Fig.5: this screen grab shows the frequency response for the low-pass filter configuration with a nominal corner frequency of 1kHz. The attenuation slope is 24dB per octave.

Fig.6: the frequency response for a high-pass filter configuration with a nominal corner frequency of 1kHz. Once again, the attenuation slope is 24dB per octave.

three dual op amps (IC1 to IC3) plus a single op amp (IC4) in the power supply section.

The first thing to note here is that the designations for the op amps used in the input buffer, filter and output stages match those shown on the block diagram of Fig.3. So, if you've followed the description for Fig.3, understanding how the full circuit works should be a snack.

As shown, the incoming audio signal is applied to unity-gain buffer stage IC1a via a 4.7µF non-polarised capacitor and a 10Ω stopper resistor. The capacitor is there to block any DC voltage, while the stopper resistor blocks any stray RF signals that may have been picked up by the leads.

IC1a is biased to Earth 2 via the associated 47kΩ resistor. This earth is at 0V for plus and minus supply rails and at half-supply (0.5Vcc) for a single supply.

IC1a's output is fed to either HP filter IC2a or to LP filter IC3a, depending on the input jumper location in the Selection Matrix. This works exactly as indicated previously in the description for the block diagram (Fig.3).

Both the high-pass and low-pass filter stages (IC2a, IC2b, IC3a and IC3b) use a multiple feedback (MFB) 2-pole arrangement. This was used in preference to the unity-gain Sallen-Key style of filter because the MFB response is less affected by component value variations due to manufacturing tolerances.

Note that 10Ω stopper resistors are included in series with the HP filter inputs. This is done in each case to prevent instability (oscillation) in the preceding stage. IC2a's output is fed to the second HP filter stage IC2b (ie, the stages are cascaded), while IC3a drives the second LP filter stage IC3b.

For an HP filter, IC2b's output is fed to level potentiometer VR1 by linking 'HPout' to 'OUT' in the Selection Matrix. Alternatively, for an LP filter, the output from IC3b is connected to level potentiometer VR1 using a jumper to link 'LPout' to 'OUT'. Again, this functions exactly as described for block diagram Fig.3.

Finally, for a bandpass arrangement, HP filter IC2b's output is fed to LP filter IC3a via a jumper link between 'HPout' and 'LPin'. IC3b's output is then fed to VR1 via a jumper link between 'LPout' and 'Out'.

Minimising noise

As stated earlier, the signal from IC1a is normally fed to the HP filter stages first ('IN' linked to 'HPin'), so that the LP filter stages can then minimise noise. Alternatively, the LP stages can be placed first by linking 'IN' to 'LPin', 'LPout' to 'HPin' and 'HPout' to 'OUT'.

The resulting audio signal on VR1's wiper is fed directly to the non-inverting input (pin 5) of IC1b. As previously stated, this amplifier has a gain of 2, but this gain reduces to 1 for frequencies above 72kHz due to the 220pF capacitor across the feedback resistor. IC1b's output appears at pin 7, and is coupled to the output terminals via a 150Ω isolating resistor and a 4.7µF NP (non-polarised) capacitor and 150Ω isolating resistor.

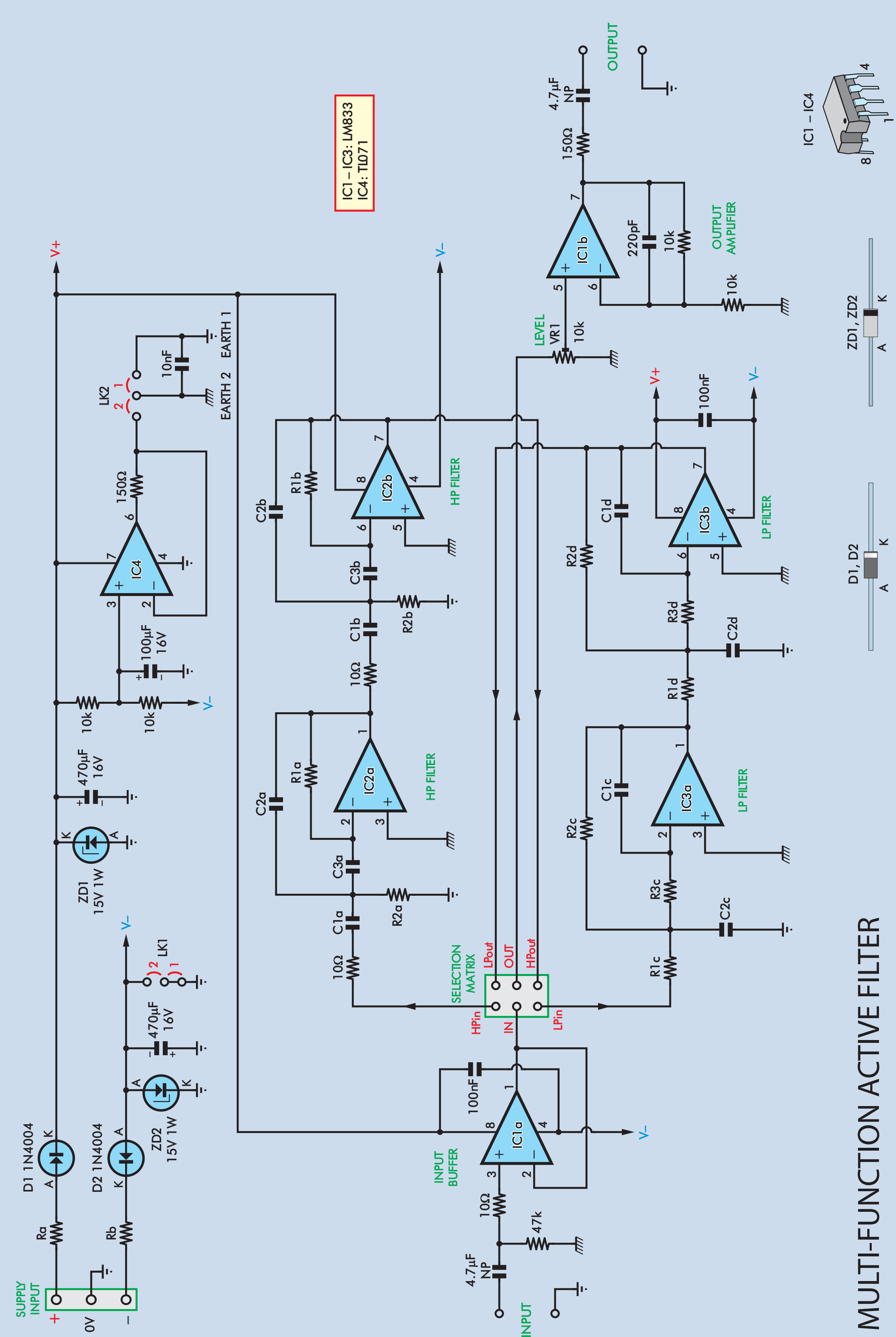
Power Supply

In operation, the Multi-Function Active Filter would typically be powered from the supply rails of the amplifier. As stated previously, options are available to power the module from dual DC supply rails or from an AC source.

The unit can also be powered from a single supply rail, such as +25V, +15V or +12V. The 12V option enables it to be used in a car.

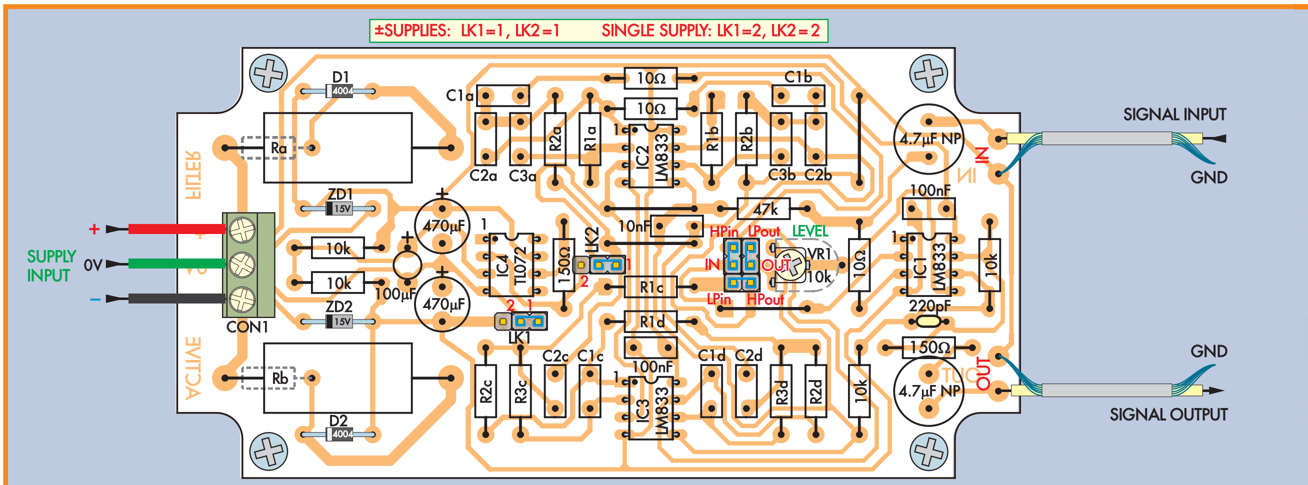
In summary, the three options for powering the module are as follows:

1) A dual-rail (plus and minus) supply of between ±15V and ±60V (this connects to the '+' and '–' supply inputs of the terminal block)
2) A single DC supply rail, ranging from 12V to 60V (this connects



MULTI-FUNCTION ACTIVE FILTER

Fig.7: the complete circuit for the Multi-Function Active Filter. IC1a serves as an input buffer stage, while op amp IC1b is the output amplifier. Cascaded op amp stages IC2a and IC2b together form the high-pass filter, while IC3a and IC3b make up the low pass filter. IC4 is used to provide a half-supply reference if the unit is powered from a single-rail power supply.



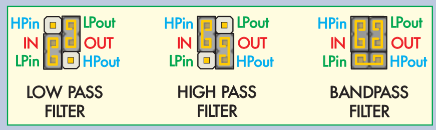


Fig.8: follow this parts layout diagram to build the PC board. The various tables show the values for resistors Ra and Rb and for the filter components (R1-R3 and C1-C2), while the linking options for the selection matrix are shown on the right. Links LK1 and LK2 go in position 1 for a dual-rail supply (or for an AC supply), but must be moved to position 2 for a single-rail supply.

between the '+' and '0V' supply inputs)

3) An AC supply, ranging from 12-43V AC (here, the '+' and '–' inputs are tied together and the AC supply is connected between these commoned inputs and the 0V input).

In the case of a dual supply, diodes D1 and D2 (1N4004) protect the circuit against reverse polarity connection. Zener diodes ZD1 and ZD2 then regulate the supply to provide ±15V rails, which are then used to power op amps IC1 to IC3. Two 470µF capacitors decouple the ±15V supply rails.

Resistors Ra and Rb are used to limit the current into ZD1 and ZD2. The values of these two resistors depend on the input voltage (see Table 3 for the required values).

In addition, for a dual supply, Earth 1 and Earth 2 are connected together by installing jumper link LK2 in position 1 (LK1 must also be in position 1 or left out). With no signal, this sets op amps IC1, IC2 and IC3 so that their outputs sit at 0V.

For a single supply, IC1 to IC3 need to be biased at half-supply so that the signal can swing symmetrically without clipping. This half-supply rail is provided by op amp IC4. As shown, a half-supply voltage is derived using two 10kΩ resistors in series across the positive supply rail. This is decoupled by a 100µF capacitor and then buffered by IC4 to drive Earth 2 when LK2 is in the '2' position.

In addition, for a single supply, the negative supply pins for IC1 to IC3 are connected to the 0V supply rail by placing link LK1 in position 2.

Note that when LK2 is in position 2, the half-supply output from IC4 is bypassed to earth (0V) via a 10nF capacitor. This prevents oscillation in the filter op amps. The 150Ω resistor at pin 6 of IC4 isolates the op amp's output from the capacitance in the shielded output leads.

Finally, for an AC supply, diodes D1 and D2 function as half-wave rectifiers to derive positive and negative supply rails. The circuit then functions exactly the same as for a dual-rail DC supply.

Construction

All parts for the Multi-Function Active Filter are mounted on a single-sided PC board, coded 812, measuring 123mm × 63mm. This board is available from the

Table 1: Resistor Colour Codes

❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	1	47kΩ	yellow violet orange brown	yellow violet black red brown
❏	1	15kΩ	brown green orange brown	brown green black red brown
❏	1	13kΩ	brown orange orange brown	brown orange black red brown
❏	1	12kΩ	brown red orange brown	brown red black red brown
❏	4	10kΩ	brown black orange brown	brown black black red brown
❏	2	6.2kΩ	blue red red brown	blue red black brown brown
❏	2	5.6kΩ	green blue red brown	green blue black brown brown
❏	2	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❏	2	150Ω	brown green brown brown	brown green black black brown
❏	3	10Ω	brown black black brown	brown black black gold brown

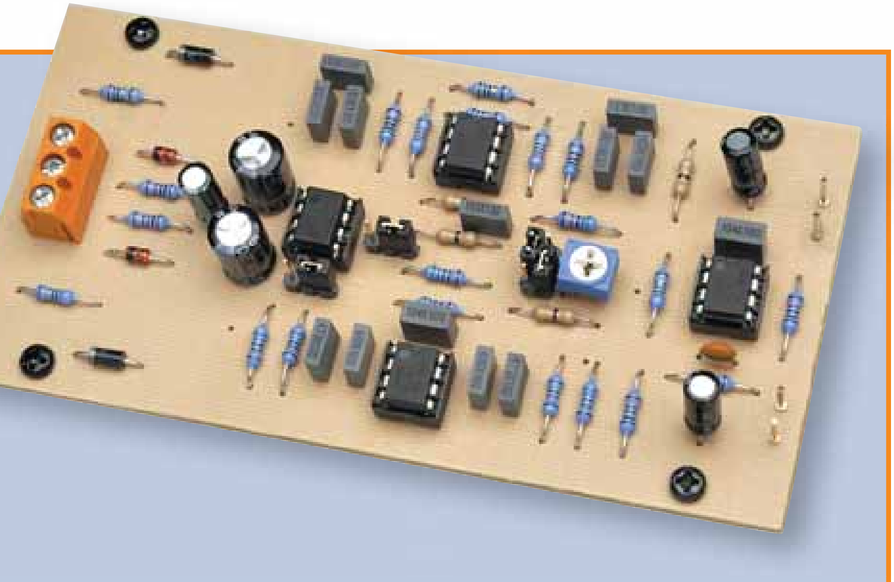


Table 2: Filter type configuration

Low-Pass Filter	High-Pass Filter	Bandpass Filter
Link IN to LPin; Link LPout to OUT	Link IN to HPin; Link HPout to OUT	Link IN to HPin; Link HPout to LPin; Link LPout to OUT

Table 3: Power supply configuration

Input Voltage	Ra	Rb	Links
±60VDC, 43VAC	1.2kΩ 5W	1.2kΩ 5W	LK1 position 1, LK2 position 1
±55VDC, 40VAC	1kΩ 5W	1kΩ 5W	LK1 position 1, LK2 position 1
±50VDC, 35VAC	820Ω 5W	820Ω 5W	LK1 position 1, LK2 position 1
±45VDC, 30VAC	680Ω 5W	680Ω 5W	LK1 position 1, LK2 position 1
±40VDC, 28VAC	560Ω 5W	560Ω 5W	LK1 position 1, LK2 position 1
±35VDC, 25VAC	470Ω 5W	470Ω 5W	LK1 position 1, LK2 position 1
±30VDC, 20VAC	390Ω 5W	390Ω 5W	LK1 position 1, LK2 position 1
±25VDC, 18VAC	270Ω 5W	270Ω 5W	LK1 position 1, LK2 position 1
±20VDC, 15VAC	120Ω 1W	120Ω 1W	LK1 position 1, LK2 position 1
±15VDC, 11VAC	10Ω 0.5W	10Ω 0.5W	LK1 position 1, LK2 position 1
+30V	390Ω 5W	NA	LK1 position 2, LK2 position 2
+25V	270Ω 5W	NA	LK1 position 2, LK2 position 2
+20V	120Ω 1W	NA	LK1 position 2, LK2 position 2
+15V	10Ω 1/2W	NA	LK1 position 2, LK2 position 2
+12V	10Ω 1/2W	NA	LK1 position 2, LK2 position 2

EPE PCB Service. The board can either be housed inside a UB3-size plastic case, measuring 130mm × 68mm × 44mm, or installed within an amplifier case. Note that corner cutouts will be required if mounting the board in the specified case, to clear the integral mounting posts.

Fig.8 shows the parts layout on the PC board. However, before starting the assembly, you have to decide on the power supply to be used, the type of filter arrangement and the cutoff frequency.

Table 3 shows the resistors (Ra and Rb) required for various power supply voltages, plus the LK1 and LK2 linking options. The filter component values are selected from Table 4 and Table 5 (see also the panel titled 'Calculating The Filter Component Values').

Note that for the single supply option, Rb, D2, ZD2 and C5 can be omitted. However, it does not matter if they are installed. Alternatively, for a dual rail supply option, IC4, R4, R5 and C6 are not required. Note also that either 5W or 0.5W resistors can be used for

Using The FilterPro Software From TI

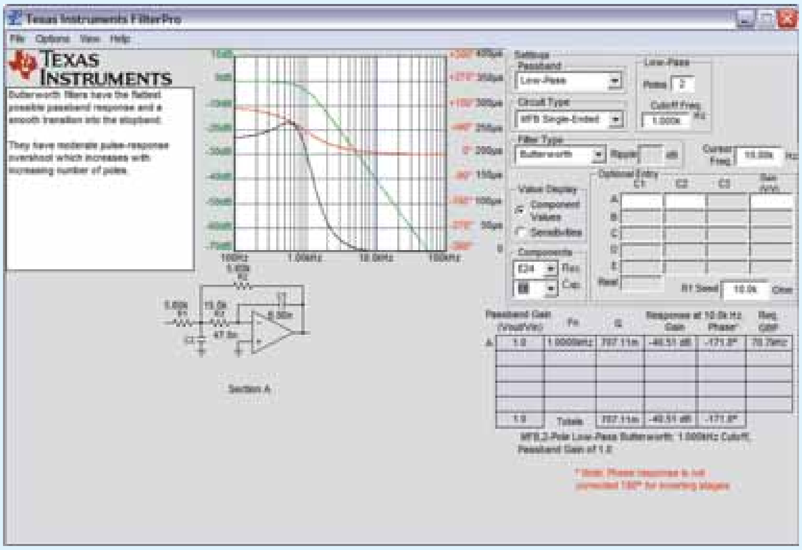


Fig.9: this is how FilterPro should look when set up to calculate values for a low-pass 2-pole Butterworth filter.

The first step here is to download the 2.848MB zipped file (available from http://focus.ti.com/docs/toolsw/folders/print/filterpro.html) and run the FilterProSetup.exe file. That done, navigate to C:\ProgramFiles\Ti Analog Design Centre\Filterpro and create a shortcut on your desktop for FilterPro.exe

When you launch FilterPro, the program will show a screen with a graph, the filter circuit and various settings (see Fig.9). The graph shows the frequency response of the filter using an amplitude versus frequency plot. The actual rolloff can be seen, as well as any excursions in the response across the passband or at the cutoff frequency.

Two other responses are also shown on the graph: the phase response and the group delay. The phase response plots the phase variations in the filter output as a function of frequency. By contrast, the group delay shows the slope (or rate of change) in the phase response, and is ideal for displaying the filter response to a pulse signal.

Several different filter types can also be selected – ie, Bessel, Butterworth and Chebychev. Each has a different 'Q' value and so the filter response differs from one to the other.

Each filter type has its own advantages and disadvantages. For example, a Bessel filter has a Q of 0.577 (1/√3) and has a smooth but drooping amplitude response across the passband. It has very little pulse response overshoot and its roll off is not as steep as for a Butterworth filter.

Butterworth filters have a 'Q' of 0.7071 (1/√2) and have the flattest possible (maximally flat) amplitude response in the passband and a moderate pulse response rise (or overshoot) at the cutoff frequency.

A Chebychev filter has a higher Q again. This filter has ripple in the passband, a steeper cutoff rate and higher pulse response overshoot compared to the two lower Q filters. The Q value depends on the amount of ripple that can be tolerated and is 0.956 for a 1dB passband ripple and 0.863 for a 0.5dB passband ripple.

A filter with a 'Q' of 0.5 is critically damped and shows no pulse response overshoot. The Bessel, Butterworth, and Chebychev filters are all under-damped and so each show some degree of overshoot in its response. An over-damped filter would have a 'Q' of less than 0.5.

Butterworth filters

For audio work, the best compromise filter type is the Butterworth, especially when two filters are cascaded, as in our Multi-Function Active Filter. So, in FilterPro, select

Calculating The Filter Component Values

CHOOSING THE CROSSOVER FREQUENCIES for loudspeaker drivers requires careful consideration. You will need the data sheet for each driver in order to make a decision as to where the crossover frequency should lie. Ideally, the crossover frequency should be well away from the driver's resonance frequency and the adjacent drivers should be a good match to ensure a smooth frequency response across the audio band.

Many books have been written on the subject and a good reference is **'The Loudspeaker Speaker Design Cookbook'** by Vance Dickason. This is available from Jaycar, Cat. BA-1400.

Once you have decided on the crossover frequencies, the filter component values can be calculated. Table 4 and Table 5 show the recommended values for a range of common frequencies.

For other frequencies, you can download software off the net to make the calculations easier. Our recommendation is to use 'Filter Pro' from Texas Instruments. You can download it from **http://focus.ti.com/docs/toolsw/folders/print/filterpro.html**

If this site becomes unavailable, do a search for 'TI filter software' or for 'FilterPro'. Information on how to use FilterPro and other useful information on filters is available at **http://focus.ti.com/lit/an/sbfa001a/sbfa001a.pdf**

An alternative on-line program is also available from Okawa Electric – see the section entitled 'Using the FilterPro Software From TI'.

Ra and Rb, as the PC board accepts both types.

For an LP filter only, there is no need to install the HP components. These include IC2, R1a, R2a, C1a, C2a, C3a, R1b, R2b, C1b, C2b and C3b. The two 10Ω stopper resistors can also be left out (but not the one on pin 3 of IC1a).

Similarly, for an HP filter only, you can leave out LP components IC3, R1c, R2c, R3c, C1c, C2c, R1d, R2d, R3d, C1d and C2d.

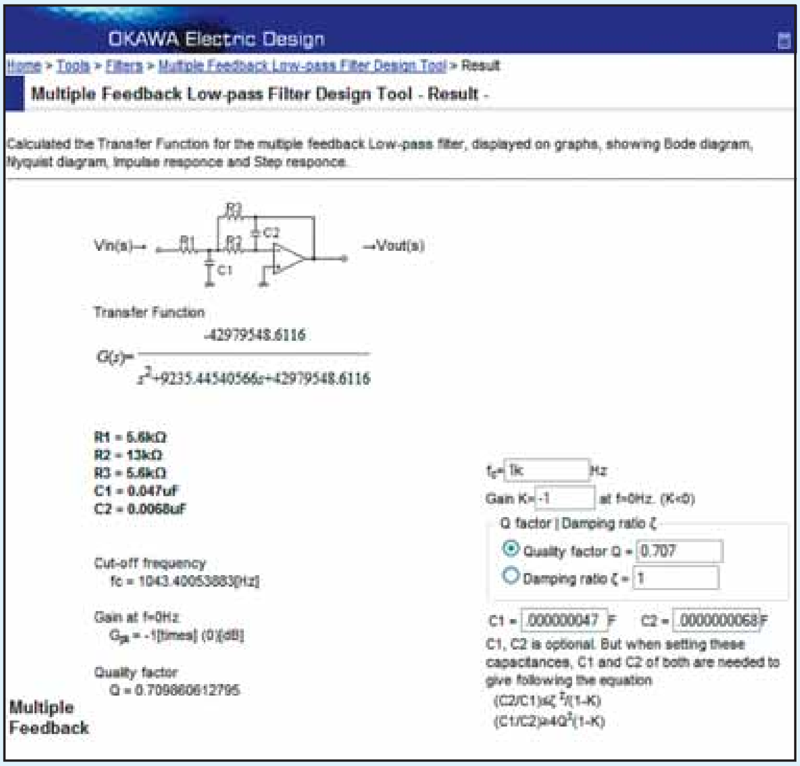


Fig.10: the low-pass filter design software from Okawa Electric shows the circuit values and filter responses in a similar way to FilterPro. A high-pass filter design tool is also available from Okawa Electric – see text.

'Butterworth' as the filter type and select '2' for the number of poles. The circuit type should be set to 'MFB single ended' and the set display value should be 'component values'.

For components, select 'E24' series for the resistors and either 'E6' or 'E12' for the capacitors (these 'E' series values select the number of values available in a decade range). The relevant resistor and capacitor values will then be calculated, based on readily available components.

Note: some component suppliers may not have the full E12 capacitor series. In that case, a recalculation may have to be made using the E6 series instead if using the E12 series gives components values that are unavailable.

The next step is to enter the cutoff frequency, select either LP or HP and then click on an unused section of the screen to start calculating the values.

Note that the circuit for the multiple feedback 2-pole filter shows the values for a single 2-pole filter section. These same values are also used in the second 2-pole filter stage of the Multi-Function Active Filter.

FilterPro provides values for the resistors and capacitors using R1, R2 and R3 and C1, C2 and C3 component designations. These are easily equated with the component designations on the circuit diagram (Fig.7) and parts layout diagram (Fig.8). Note: the a, b, c and d designations on Fig.7 are there simply to distinguish one filter circuit from another.

Bandpass filter

A bandpass filter is made by designing two separate cascaded HP and LP circuits. For example, if you want a bandpass filter with roll offs at 500Hz and 2kHz, you simply use FilterPro to design independent 500Hz high-pass and 2kHz low-pass stages.

Do not select a bandpass design in FilterPro – the calculations are not applicable to the Multi-Function Active Filter module described here.

Alternative software

If you want to use an alternative program to FilterPro, or if you want to check the predicted response of your filter using the values given by FilterPro, a good online program is one from Okawa Electric. For the low-pass filter, go to http://sim.okawa-denshi.jp/en/OPtazyuLowkeisan.htm For the high-pass filter navigate to http://sim.okawa-denshi.jp/en/OPtazyuHikeisan.htm

These sites not only allow you to calculate filter components, but also allow you to input component values. The program will then show the actual cutoff frequency, filter Q and other features. These calculations can sometimes give a better result (ie, closer to the required Q and cutoff frequency) than FilterPro.

Note, however, that the R1, R2, R3, C1, C2 and C3 labelling is a little different to that of the FilterPro and our circuit, so make sure you transpose the labelling correctly. Also, do not forget to tick the Q value field at 0.707 rather than using the ticked damping ratio field of 1 for the calculation.

Board assembly

Start the assembly by carefully inspecting the board for any defects in the copper tracks, then install the four wire links. Alternatively, 0Ω resistors can be used instead of the wire links. These look similar to a 0.25W resistor, but have just one single black band around the centre of the body.

Next, install four PC stakes at the input and output positions, then install the resistors and trimpot VR1. Table 1 shows the resistor colour codes, but a digital multimeter (DMM) should also be used to check values, just to make sure.

Follow these with the diodes, Zener diodes and the ICs. These parts must all be installed with the correct orientation. Note that IC4 is a different type to IC1, IC2 and IC3, so don't get it mixed up. We used IC sockets for the ICs and these sockets also have an orientation notch at one end – see Fig.8.

The electrolytic capacitors are next on the list and these must also be oriented correctly. The only exceptions here are the two 4.7µF NP (non-polarised) types which can go in either way around.

Once these parts are in, install the two 3-way SIL (single in-line) headers for links LK1 and LK2. The two jumpers can then be fitted to these headers. They both go in position 1 for a dual-rail supply (or if you are using an AC supply) – see Table 3.

Table 4: High-pass filter component values (Butterworth response)					
Frequency	C1 (IEC Code) (EIA Code)	C2 (IEC Code) (EIA Code)	C3 (IEC Code) (EIA Code)	R1	R2
50Hz	330nF (334)	330nF (334)	330nF (334)	20kΩ	4.3kΩ
100Hz	150nF (154)	150nF (154)	150nF (154)	22kΩ	5.1kΩ
120Hz	150nF (154)	150nF (154)	100nF (104)	24kΩ	4.7kΩ
150Hz	100nF (104)	100nF (104)	100nF (104)	22kΩ	5.1kΩ
200Hz	68nF (683)	68nF (683)	100nF (104)	20kΩ	4.7kΩ
300Hz	47nF (473)	47nF (473)	68nF (683)	20kΩ	4.7kΩ
500Hz	33nF (333)	33nF (333)	33nF (333)	20kΩ	4.3kΩ
1kHz	15nF (153)	15nF (153)	15nF (153)	22kΩ	5.1kΩ
1.5kHz	10nF (103)	10nF (103)	10nF (103)	22kΩ	5.1kΩ
2kHz	6.8nF (6n8) (682)	6.8nF (6n8) (682)	10nF (103)	20kΩ	4.7kΩ
3kHz	6.8nF (6n8) (682)	6.8nF (6n8) (682)	6.8nF (6n8) (682)	20kΩ	4.7kΩ
5kHz	3.3nF (3n3) (332)	3.3nF (3n3) (332)	3.3nF (3n3) (332)	20kΩ	4.3kΩ
10kHz	1.5nF (1n5) (152)	1.5nF (1n5) (152)	1.5nF (1n5) (152)	22kΩ	5.1kΩ
20kHz	680pF (681)	680pF (681)	1nF (102)	20kΩ	4.7kΩ

Table 5: Low-pass filter component values (Butterworth response)					
Frequency	R1	R2	R3	C1 (IEC Code) (EIA Code)	C2 (IEC Code) (EIA Code)
50Hz	5.6kΩ	5.6kΩ	12kΩ	150n (154)	1µF (105)
100Hz	5.6kΩ	5.6kΩ	15kΩ	68nF (683)	470nF (474)
120Hz	4.7kΩ	4.7kΩ	12kΩ	68nF (683)	470nF (474)
150Hz	5.6kΩ	5.6kΩ	13kΩ	47nF (473)	330nF (334)
200Hz	6.2kΩ	6.2kΩ	15kΩ	33nF (33)	220nF (224)
300Hz	6.2kΩ	6.2kΩ	13kΩ	22nF (223)	150nF (154)
500Hz	5.6kΩ	5.6kΩ	12kΩ	15n (153)	100nF (104)
1kHz	5.6kΩ	5.6kΩ	15kΩ	6.8nF (6n8) (682)	47nF (473)
1.5kHz	5.6kΩ	5.6kΩ	13kΩ	4.7nF (4n7) (472)	33nF (333)
2kHz	6.2kΩ	6.2kΩ	15kΩ	3.3nF (3n3) (332)	22nF (223)
3kHz	6.2kΩ	6.2kΩ	13kΩ	2.2nF (2n2) (222)	15nF (153)
5kHz	5.6kΩ	5.6kΩ	12kΩ	1.5n (1n5) (152)	10nF (103)
10kHz	5.6kΩ	5.6kΩ	15kΩ	680pF (681)	4.7nF (4n7) (472)
20kHz	6.2kΩ	6.2kΩ	15kΩ	330pF (331)	2.2nF (2n2) (222)

Be sure to choose the correct filter component values when building the PC board – see Tables 4 and 5. In this case, the board has been configured as a high-pass filter, and is set up to accept dual supply rails.

Alternatively, install them both in position 2 if you intend using a single rail supply.

The selection matrix requires a 3-way DIL (dual in-line) pin header and this should now be installed – it goes in just to the left of trimpot VR1. Once it's in, install the jumpers on this header to select your filter type (ie, LP, HP or bandpass).

The assembly can now be completed by installing the 3-way terminal block.

Power supply checks

Before applying power, check that the supply link options are correct (see Table 3) and that the correct values have been installed for resistors Ra and Rb. Check also that you've installed the correct link options for the filter type.

Next, connect one probe of your DMM to the 0V supply input, apply power and use the other probe to measure the supply voltages on the ICs. For a dual (±) or AC supply arrangement, check that there is +15V on pin 8 of IC1 to IC4. Similarly, there should be –15V on pin 4 of IC1 to IC3, while pin 4 of IC4 (if installed) should be at 0V.

For the single supply arrangement, check for +15V on pin 8 of ICs1-3 and on pin 7 of IC4 (if installed). Note that the measured voltage will be lower if the supply voltage is less than 15V. Pin 6 of IC4 should be at half-supply (eg, 7.5V for a 15V supply). ***EPE***

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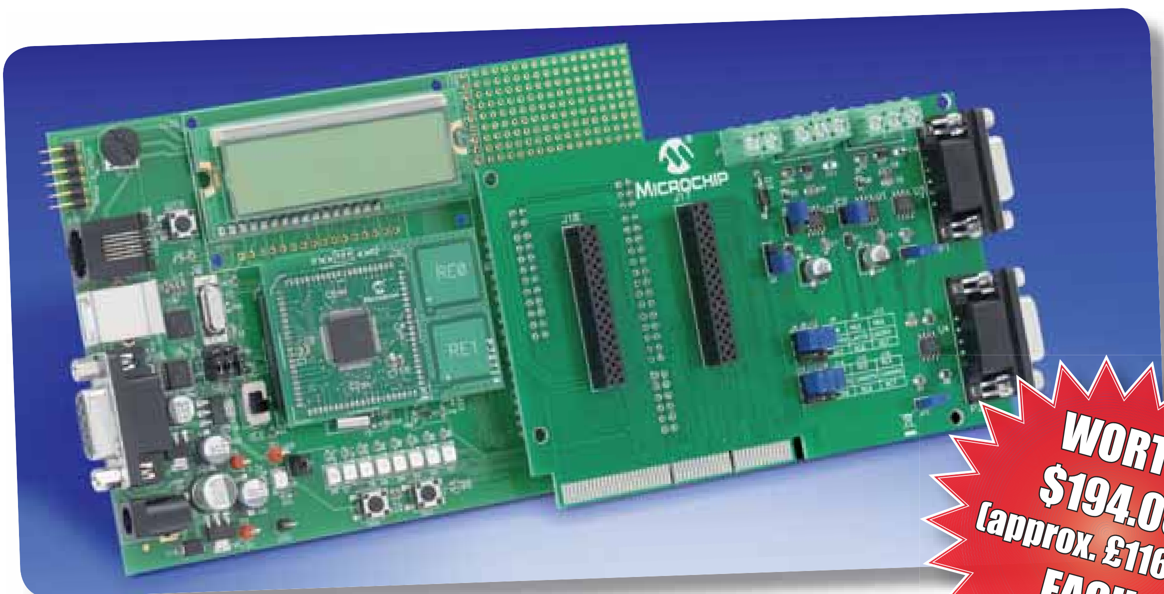

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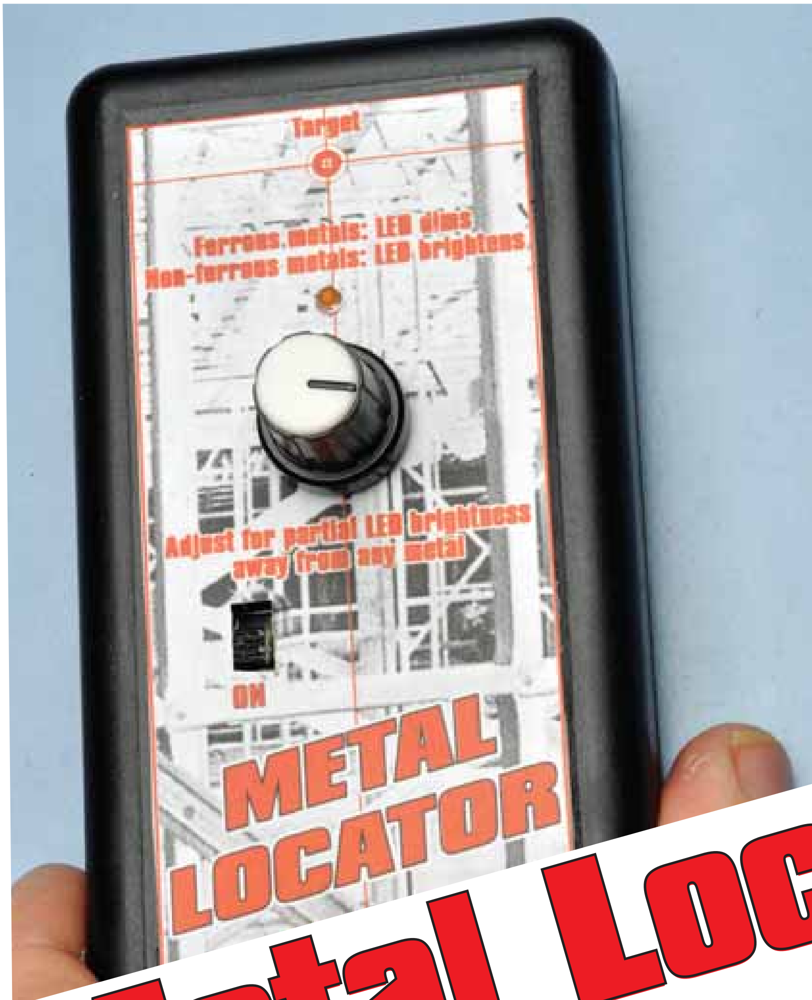


Ideal for finding steel frames and studs, steel bracing and nails in plaster walls, this Metal Locator can also show the length of the tang in knife handles, screwdrivers and other tools. Plus, it can discriminate between ferrous and non-ferrous metals.

Metal Locator

By JOHN CLARKE

IF YOU want to hang pictures, shelving or mirrors on a plaster wall in a steel-framed building it is useful to find where the metal studs are.

You may wish to secure your screws to the stud or alternatively, you may wish to avoid the stud and attach directly to the plaster wall using suitable fasteners. There are also other hidden items within the wall that should be located before drilling, such as metal bracing straps, screws and nails.

Metal locator

With the *Metal Locator* you can find the metal stud positions as well as any steel bracing, screw heads and nails. That is, provided the metal is no deeper than 25mm inside the wall. For small nails in wooden studs, it can detect them provided that the heads are within 10mm of the wall surface. Naturally, this device does not locate the timber studs themselves, nor can it find steel frames in walls that have a cladding thicker than 25mm (a very unusual wall, especially inside). Nor can it detect power cables inside walls.

The Metal Locator can distinguish between ferrous and non-ferrous metals. Ferrous metals include mild steel, stainless steel (both magnetic and non-magnetic), wrought iron, high tensile steel, galvanised iron, tin-plated steel (steel cans or tinplate), passivated steels and cast iron. Non-ferrous metals include copper, brass, zinc, aluminium, gold, silver, lead and tin.

In the presence of ferrous metals, the LED on the Metal Locator dims. Conversely, the LED brightens in the presence of non-ferrous metal. For ferrous metals, the sensitivity knob is adjusted so that the LED is reasonably bright in the absence of the metal. The LED then dims in the presence of ferrous metal.

To detect non-ferrous metals, the sensitivity is adjusted so that the LED is dim in the absence of the metal. The LED will then brighten in the presence of the non-ferrous metal. Greater sensitivity can be had with the LED just glowing in the absence of metal for detection of either metal type.

Specifications

Detection range: up to 25mm from the underside of the case

Current drain: <20mA with LED fully lit

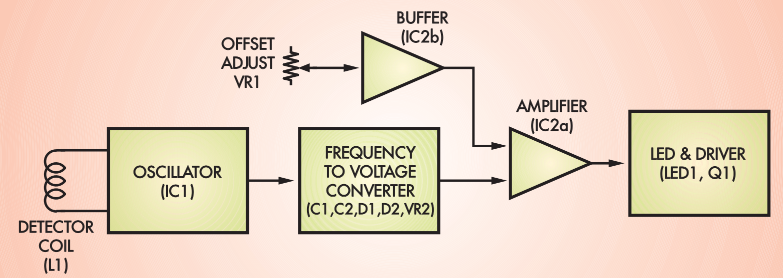


Fig.1: the block diagram has the same functionality as the circuit below.

The Metal Locator is housed in a compact plastic case that includes a 9V battery compartment. On the lid are the on/off switch, sensitivity control and the indicating LED.

How it works

The block diagram of the Metal Locator is shown in Fig.1. It is based on an astable oscillator controlled by the detector coil, L1. The oscillation frequency changes with the presence of metal. For ferrous metals, the frequency decreases, while for non-ferrous metals the frequency increases.

The oscillator's output is fed to a frequency-to-voltage converter. Small frequency changes are then detected as voltage changes that can easily be amplified before driving the LED. The LED brightness varies with a change in frequency from the oscillator.

An offset adjustment using VR1 allows the LED brightness to be set at a very low level to brighten with non-ferrous metals. The LED can be set at a higher level to detect ferrous metals where the LED begins to dim.

The buffer stage (IC2b) between the offset control and the amplifier is there to ensure there is no gain change with adjustment of potentiometer VR1.

Circuit details

The full circuit diagram in Fig.2 is based on just two ICs. One is a CMOS version of the 555 timer (IC1) and the other is a general-purpose LM358 dual op amp (IC2a and IC2b).

IC1 operates as an unconventional astable oscillator. To explain how it works, we will compare it to a conventional 555 astable oscillator, as shown in Fig.3. This has resistor R1 between its output at pin 3 and both the trigger and threshold inputs at pins 2 and 6. Capacitor Cx is connected between pin 2, pin 6 and ground.

Initially, when power is first applied, the capacitor is discharged and the trigger input at pin 2 is at 0V. At this stage, the timer is triggered and the output at pin 3 goes high to equal the positive supply rail voltage.

The capacitor now charges via R1. When the capacitor charges to the pin 6 threshold voltage (2/3 supply), the pin 3 output goes low (to 0V) and the capacitor now discharges via R1. When the capacitor voltage discharges to the trigger level voltage at pin 2 at 1/3 the supply, the pin 3 output goes high again to recharge the Cx capacitor. The process continues, and so pin 3 produces a square wave output with the frequency determined by R1 and Cx.

In the circuit of Fig.2, we substitute inductor L1 for R1 and R1 (470Ω) for capacitor Cx. It now operates as follows.

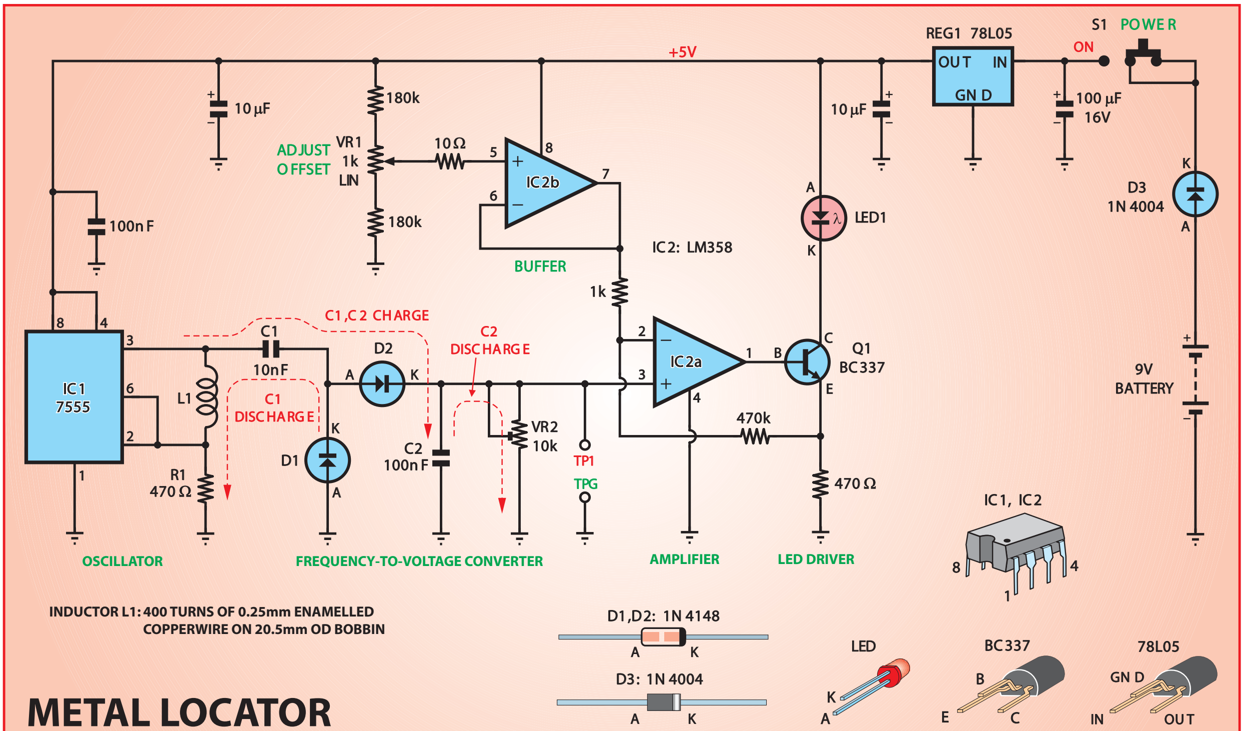


Fig.2: the Metal Locator circuit is based on two low-cost ICs and a handful of other cheap components.

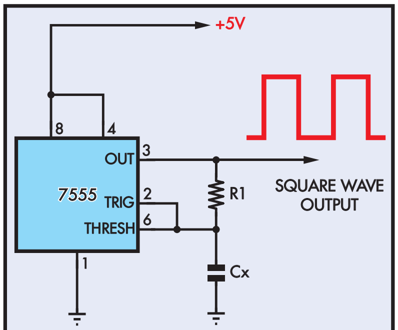
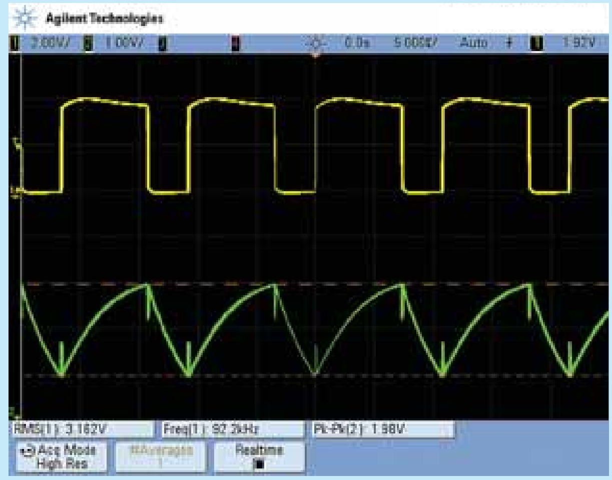


Fig.3: here's a 'traditional' 555 oscillator circuit with the frequency determined by R_1 and C_X. But as you can see in Fig.2, it's possible to substitute an inductor and resistor to make it oscillate.



And here's the proof! The top trace is the waveform at pin 3, while the green trace shows the waveform at pin 6. The waveform at pin 6 is the voltage across R1, and this shows that the current through R1 does not reverse; it merely varies between about 3.5mA and 7mA. Note the spikes generated each time the 555 changes state.

At the instant of power being applied, inductor L1 is effectively a high impedance and resistor R1 pulls the pin 2 input below the 1/3 supply threshold to trigger the pin 3 output to go high.

Current then begins to flow through L1 and R1. As the current rises, the voltage across R1 increases until it reaches the 2/3 supply voltage threshold. This changes the state of the oscillator so that pin 3 goes low. The current through L1 does not change direction, but ramps down until the voltage across R1 drops below the 1/3 supply threshold to retrigger the timer and pin 3 goes high again.

Oscillator frequency

The frequency is dependent upon the inductance of L1 and the resistance of R1 (which is fixed at 470Ω). Inductor L1 is an air-cored coil of wire. If metal comes close to this coil its inductance will change and this will alter the frequency of oscillation. For ferrous metals, the inductance will increase and the frequency of oscillation will fall. For non-ferrous metal, the inductance will decrease and the oscillation frequency will increase. The frequency is around 94kHz and changes by up to 2kHz with metal near the coil.

The output from IC1 is fed to a diode pump comprising capacitors C1 and C2, preset VR2 and diodes D1 and D2. It functions as a frequency-to-voltage converter by dint of the size of C1, which is fairly small at only 10nF. This means that the DC voltage developed across C2 will vary as the frequency varies; it will be higher as the frequency increases and this allows the circuit to discriminate between ferrous and non-ferrous metals as the apparent inductance of L1 is changed.

The DC voltage across C2 is amplified by op amp IC2a. This has a gain of about 470 (471 to be precise), set by the 1kΩ and 470kΩ feedback resistors. IC2a is buffered by transistor Q1 to provide a higher current drive for LED1.

Offset control

Op amp IC2a has an offset control (VR1) to enable adjustment of the LED brightness. In effect, the operating point of IC2a can be shifted up or down by varying the voltage applied to its inverting input. The varying voltage comes from IC2b, a unity-gain buffer that is fed by the wiper (moving contact) of the 1kΩ potentiometer VR1. Combined with the 180kΩ divider resistors, the range amounts to about 14mV.

The buffer stage of IC2b ensures the gain of IC2a is kept at 471 and is not affected by the resistance at the wiper of VR1. Any voltage change in VR1 is amplified in IC2a by 471, so the 14mV variation allows the IC2a output to be shifted over its full output range, from very close to 0V up to about 3.5V.

This adjustment allows the LED to be set at the required brightness for metal detection. In effect, VR1 operates as a sensitivity control for the circuit.

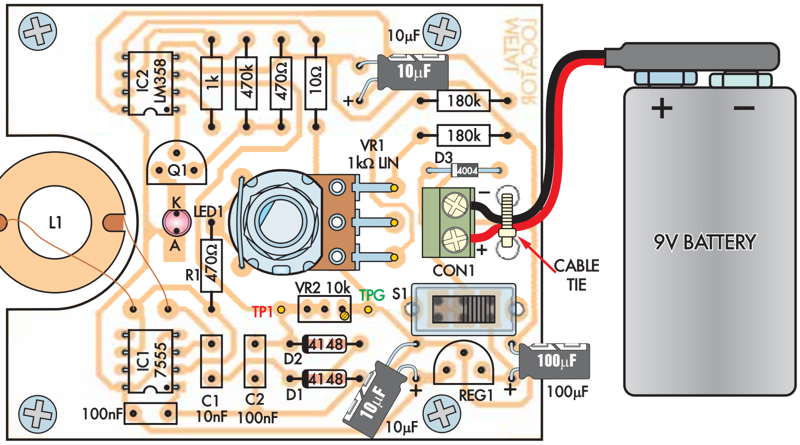
Trimpot VR2 provides a further range of adjustment. For optimum operation of VR1, VR2 is adjusted so the voltage at TP1 is at about half supply, or

Why Not Use A Stud Finder?

Most readers know that stud finders are cheaply available from hardware outlets and even from bargain stores. They often have three functions: stud, nail and power.

While they are cheap and readily available, they can give misleading results when looking for screws or metal studs in walls.

Nor can they discriminate between ferrous and non-ferrous metals and their sensitivity cannot be adjusted.



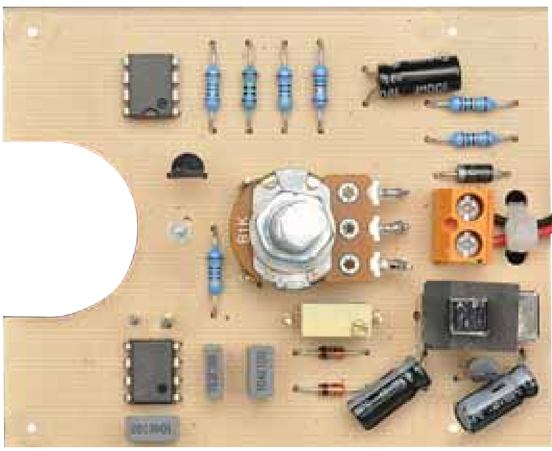


Fig.4 (top): the component layout for the Metal Locator, with the same-size photo prior to mounting in the case at left. Note the electrolytic capacitors need to be mounted folded over so they are flat on the PC board.

+2.5V. This matches the nominal 2.5V available from the wiper of VR1 at its centre position.

The circuit is powered from 5V, derived from a 9V battery and a 5V regulator (REG1). Diode D3 prevents damage to the 100µF capacitor and the 5V regulator if the battery is connected the wrong way around. The 5V supply is decoupled with a 10µF capacitor at REG1's output and another 10µF capacitor at the supply rails for IC2. IC1 has a 100nF supply bypass capacitor.

Construction

Construction involves mounting all parts, except coil L1, on a single PC board. This is coded 810, measures 78mm × 64mm and is housed in a remote control case measuring 135mm × 70mm × 24mm. This board is available from the *EPE PCB Service*.

Checking Handles: Knives or Screwdrivers

The handles on some kitchen knives are unsafe because they have a very short tang. The Metal Locator can show just how long the metal tang goes into the handle of a kitchen knife or screwdriver. Many professional knives have the tang extending the whole length of the handle, and this tang can be seen running between the two handle sections that are riveted to the outside of the tang.

But some low cost knives only have a tang that enters part way into a plastic moulded handle. They can even have imitation rivets along the handle to give the impression that the tang runs along the whole handle length. A short tang means that if a large amount of stress is applied to the handle when using the knife it is liable to break. This can be dangerous, especially when doing heavy work such as cutting up pumpkins. Make sure you use a knife that is safe for the job.

The component overlay diagram is shown in Fig.4. Begin construction by checking the PC board for shorted tracks or breaks in the copper. Check the hole sizes as well. The corner mounting holes should be 3.5mm (9/64 inch) diameter, as can the two holes to anchor the battery snap leads with the cable tie. Power switch S1 also mounts on the board – before assembly, check that its holes are large enough and if not, enlarge slightly.

Now you can begin the assembly. Install the seven resistors first. We show their colour codes in a table, but it is a good idea to also check the values using a digital multimeter before installing each onto the PC board. Make sure you don't mix up the side-by-side 470Ω and 470kΩ resistors. Doing so may not let any smoke out, but it certainly won't work when completed.

Next, install the five PC solder stakes for VR1, the two stakes to terminate inductor L1 and the two stakes for test points TP1 and TP GND. Install diodes D1 to D3 and take care to orient these correctly. IC1 and IC2 can now be installed, making sure that the 7555 timer is placed in the IC1 position and LM358 in IC2. Each IC must be oriented with the notch as shown on the overlay diagram. You might find some ICs don't have a notch, but will have a small dimple marking pin 1.

Transistor Q1 and voltage regulator REG1 can now be installed, but make sure each is placed correctly, as they look very similar to each other.

Next, LED1 can be installed, again taking care to get the orientation correct. The top of the LED should be 15mm above the PC board. The capacitors can also be installed. The three electrolytic types need to be oriented with the polarity shown, but they also need to lie down to provide clearance in the box – see photo above.

Trimpot VR2 can be installed either way around. Switch S1 is mounted as high as possible on the PC board, but with about 1mm of pin length under the PC board to allow soldering. Screw terminal block CON1 can now be installed.

Cut the shaft of the 1kΩ potentiometer (VR1) to a length of 12mm. VR1 sits vertically with its back on the PC board surface and is secured in place by soldering the potentiometer case to the associated PC stakes. To be certain solder will adhere to the surface, the

Parts List – Metal Locator

1 PC board, code 810, available from the *EPE PCB Service,* size 78mm × 64mm
1 remote control case 135mm × 70mm × 24mm (Jaycar HB 5610 or equivalent)
1 front panel label 50mm × 115mm
1 9V battery, with clip and leads
1 DPDT PC mount slider switch (S1)
1 coil bobbin 20.5mm OD × 13mm ID × 10.5mm high
1 13m length of 0.25mm enamelled copper wire
1 knob to suit potentiometer
1 2-way screw terminal with 5.08mm pin spacing
4 T0-220 insulating bushes (used as spacers)
4 M3 × 4mm screws
1 20mm diameter × 12mm heat-shrink tubing
1 100mm cable tie
9 PC stakes

Semiconductors
1 7555, LMC555CN CMOS timer (IC1)
1 LM358 dual op amp (IC2)
1 78L05 three terminal 5V low-power regulator (REG1)
1 BC337 *NPN* transistor (Q1)
1 1N4004 1A diode (D3)
2 1N4148 signal diodes (D1,D2)
1 3mm high brightness red LED (LED1)

Capacitors
1 100µF 16V PC electrolytic
2 10µF 16V PC electrolytic
2 100nF MKT polyester
1 10nF MKT polyester

Resistors (1% 0.25W)
1 470kΩ 2 180kΩ 1 1kΩ
2 470Ω 1 10Ω
1 1kΩ linear 16mm potentiometer (VR1)
1 10kΩ 25-turn top-adjust trimpot (3296W type) (VR2)

Here's the completed PC board screwed into the plastic 'remote control' case. The coil is not attached to the PC board – it is glued in place to the case in the cutout provided in the PC board.

This full-size front panel artwork fits into the recess on the top of the remote control case.

passivated coating on the pot case must be removed by scraping with a knife or file where the PC stakes are positioned. The potentiometer terminals are soldered to the remaining three PC stakes.

The 9V battery leads pass through one of the battery compartment holes in the plastic case before inserting them into the screw terminals. A cable tie secures the wires in position.

The PC board is raised by about 1mm by placing a TO-220 bush into each mounting hole from the underside of the PC board. This raises the PC board sufficiently so that the switch slider is above the top of the case lid.

Secure the PC board to the case with four M3 screws that go into the integral support bushes of the case.

Winding the inductor

Inductor L1 is wound with 400 turns of 0.25mm enamelled copper wire on a plastic bobbin. The windings are jumble wound. This means windings do not have to be placed neatly side-by-side, layer-by-layer.

The winding is held in place with a 12mm length of 20mm heatshrink tubing over the outside of the bobbin. There is no need to shrink the tubing down.

The bobbin is secured to the base of the case in the cut-out area reserved for it at the front of the PC board. We used silicone sealant to glue the bobbin in place.

Scrape off the enamel coating on each wire end with some fine grade abrasive paper and then solder them to the two PC stake terminals – it doesn't matter which way around.

Table 1: Resistor Colour Codes

No.	Value	4-Band Code (1%)	5-Band Code (1%)
1	470kΩ	yellow violet yellow brown	yellow violet black orange brown
2	180kΩ	brown grey yellow brown	brown grey black orange brown
1	1kΩ	brown black red brown	brown black black brown brown
2	470Ω	yellow violet brown brown	yellow violet black black brown
1	10Ω	brown black black brown	brown black black gold brown

A close-up of the coil (L1). It's about 400 turns of wire on a plastic bobbin.

Test and set-up

Apply power and check that there is 5V between TP GND and pin 4 and pin 8 of IC1, and 5V between TP GND and pin 8 of IC2. Depending on the regulator, the voltage could be anywhere between 4.85 and 5.15V.

Connect your multimeter between TP GND and TP1 and adjust trimpot VR2 for a reading of about 2.5V. Now set VR1 to its centre position and adjust VR2 until the LED just lights.

Using it

When the Metal Locator is first switched on and the LED is adjusted so that it glows dimly, there is a start up drift over about 10 seconds. During this period, the adjustment will have to be altered to track the change in LED brightness. It is best to wait for the warm up period before using the Metal Locator.

The sensitive area is directly under the target printed on the top side of the case (which, of course, lines up with the middle of coil L1). So, for detecting metal in a plaster wall, the case is slid over the wall to detect a change in the LED brightness.

The adjust knob will need to be set to show some LED brightness in the absence of metal objects. The sensitivity to metal is dependent on this adjustment.

If the LED brightness is set too high then there will not be a noticeable change in brightness with the unit in proximity to a metallic object.

The LED will dim for ferrous and brighten for non-ferrous metals. ***EPE***

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The electronics of earthquakes

TechnoTalk

Mark Nelson

The law of unexpected consequences certainly applies to earthquakes. Mark reports on some of the odd discoveries following the disastrous seismic activity in New Zealand.

HERE in Britain, we can feel grateful that we do not suffer the kind of dreadful earthquakes and tsunamis that New Zealand and Japan have been suffering. Actually, we do, but they occur extremely infrequently and on a smaller scale. Nevertheless, in January 1607, the land around the Bristol Channel was inundated by what Prof. Simon Haslett of Bath Spa University states was a tsunami.

Accounts tell of 'huge and mighty hills of water' advancing 'faster than a greyhound can run' that swept away villages and drowned more than 2000 people. The book *Earthquake in England* by John Thomas records numerous historical earthquakes in Britain too, including one in 1938 that even rocked Broadcasting House in London and the television tower at Alexandra Palace.

Humour in Christchurch

Last September's earthquake in New Zealand was the most damaging in 80 years and many home and business owners have had to come to terms with the fact that there will be no compensation for 'loss of value', and it may not be possible to insure new buildings. Rent and mortgages still have to be paid on useless buildings.

Our practical electronicist in Christchurch has retained his sense of humour and reports that a woman, who thought she was doing the right thing, rang her electric power supplier to disconnect the supply because she thought it might be hazardous. She was told that they would have to read the meter and that there would be a $40 charge.

No problem with that she told them, although she was a bit put out by having to pay for a meter reading. 'You'll find the meter under a ton of rubble.'

Spooky stuff

Our New Zealand friend continues that several people reported seeing blue or blue-green lights in the sky shortly before the quake struck. A National Geographic television programme aired earlier this year stated that lights in the sky were reported before the big Kobe earthquake of 1995 – the biggest to hit Japan for 47 years – and have also been reported in Peru prior to large quakes.

Here we move into one of the strangest and more controversial electronic phenomena. The popular name for these apparitions is 'earth (or earthquake) lights', which are seemingly electromagnetic. Observed only by night and close to the ground, they take on glowing, polymorphous forms, the result of seismic pressures associated with the constantly rising and falling tectonic stress in the earth's crust, creating plasma electricity above the ground.

It has to be admitted that earth lights are a fringe science, rather like UFOs, and attract a lot of interest from non-scientific people who revel in the mysterious and unexplained. The International Earthlight Alliance (IEA) is an organisation of technical professionals (scientists and engineers) who are dedicated to the scientific investigation of earth lights. Their website explains that glowing balls of light have been reported far back into history.

Until recently, stories and observations of lights from all over the world were considered superstitious lore, scientists writing them off. In the last 25 years, however, the development of high speed film and low-light digital photography have enabled observers to document the existence of these glowing lights as a valid physical phenomenon.

How they work

What is it that causes the air to glow at certain locations? Does it require a large amount of energy either below or above the ground? Could this energy be harnessed as an alternative energy source? Could a better understanding of the mechanism of the lights give an insight into earthquake forecasting?

It's hard to tell, but some sightings obviously have explainable causes, such as vehicle or aircraft lights, fires and marsh gas. One of the most plausible explanations suggests the lights come from strain building up in the earth's crust through various processes, such as tectonic activity, tidal action and human activity, dams and reservoirs.

Dr. Michael Persinger and Dr. John Derr have both hypothesised that strain fields within the earth's crust may produce electromagnetic discharges that can manifest by becoming visible as a moving body of light. The geophysicist Marsha Adams has observed fluctuations in extremely low frequency (ELF) electromagnetic emissions prior to earthquakes.

Reports of light observations have been made over a large radius from the epicentre of large earthquakes before they occur, although not in all seismically active areas. Moreover, these lights are also seen in areas of low seismic activity, meaning that the strain theory is not a universal explanation.

Another theory

Volcanic activity is at the root of another explanation. Many observations of earth lights have been made around volcanoes, for instance in Mexico. It is suggested that ultra low frequency (ULF) electromagnetic waves may trigger a process that causes light.

Significant anomalous changes in the ULF range (around 0.01Hz) have been recorded in both geoelectric and geomagnetic fields before major volcano-seismic activity. One hypothesis is that these anomalous electromagnetic discharges may trigger a process that causes a visible moving body of light, similar to the tectonic strain theory.

Earth lights in the UK

Do earth lights occur in the UK? Paul Devereux, who coined the term in 1982, is convinced they do. In an article he cites numerous historical reports, although the majority appear to relate to marsh gas or ball lightning. On the other hand, Harlech (which is adjacent to one of Britain's most active seismic zones) was, in 1984, the epicentre of a significant earthquake that measured 5.5 on the Richter scale.

A resident told Devereux that he saw, the evening before the quake, a brilliant white light the size of a small car float in from the sea and dissolve in sand dunes. Other reports from Harlech are recounted in the online article.

Unfortunately there appear to be few opportunities for electronics enthusiasts to record, let alone observe, earth lights, but the underlying theory is a fascinating subject to follow.

Further reading

- Wikipedia article: http://en.wikipedia.org/wiki/Earthquake_light
- International Earthlight Alliance: www.earthlights.org
- Paul Devereux's article: www.forteantimes.com/features/articles/58/unidentified_atmospheric_phenomena.html

LOOP ANTENNA AND AMPLIFIER

for long-distance AM radio reception

Design by Branko Justic*
Words by Ross Tester

- Listen in to AM radio stations you only dreamed existed!
- Separate close stations
- Suits upper AM broadcast band
- Small enough for flats and home units

* Oatley Electronics

ONCE upon a time, listening to long-distance radio signals (whether on the broadcast or shortwave bands, or even the amateur bands) was a popular hobby.

Hours upon hours were spent, listening for that elusive station... the ability to bring very weak stations 'out of the mud' was the ultimate thrill.

In the 21st century (and at the risk of earning the ire of diehard shortwave listeners) those days have all but gone. Today, there is little interest in the big, high-performance communications receivers of last century. A lot of gear came out of WWII, perhaps modified, but there was also an enormous amount of commercial receiver equipment on the market, reflecting the popularity of 'listening'.

Who can forget (if you were around 50 years ago) the Marconis, Hallicrafters or Gelosos, the Nationals, Eddystones, Collinses or the build-it-yourself Heathkits?

Those who still indulge in the art of 'listening' are these days just as likely to use WinRadio in/on their PCs – which in many ways outperforms even the best of the communications receivers of yore.

In fact, the vast majority of receivers today have little more than the AM and FM broadcast bands.

The aerial

There are three things which make a receiver 'good'. Two are fixed (at the whim of the designer or manufacturer).

First, the receiver's sensitivity, which is its ability to resolve very weak stations. Second, the receiver's selectivity, which is its ability to separate stations whose transmit frequencies are very close. Note that NO receiver, on its own, can separate stations which are on the same frequency.

However, the third factor, which can often help a receiver distinguish between stations on adjacent frequencies (and even sometimes the same frequency) is the aerial or antenna.

Even though the terms are virtually interchangeable these days, no self-respecting old-timer would ever call his aerial an antenna. Antennas were those small flimsy things designed to pick up TV!

Black art

Unless you have made an in-depth study of aerial/antenna theory, most people (many electronics hobbyists included) view it as a 'black art'.

Here's the top PC board mounted inside a low-cost weatherproof case. The two cables entering at left are for the loop antenna above (you can just see the loops behind the case lid). All four wires in this cable are soldered to the underside of the board together. The cable entering in the middle is the downlink – this cable has all four wires individually soldered to the underside of the PC board .

Sure, everyone knows aerials/antennas are the 'inductor' part of a tuned circuit which, depending on the antenna length, resonates at a particular frequency, according to the formula: $1/2\pi\sqrt{(LC)}$
where L is the inductance in henries and C is the capacitance in farads.

Wanted frequencies (ie, the station you want to listen to) can pass virtually unhindered, but (at least theoretically) all other frequencies are rejected.

If you make the frequency of the tuned circuit variable, then you have a means of tuning over a specific band of frequencies.

Well, at least that's the way it's supposed to work. Old timers will tell you they used to use another aerial formula: 'as long and as high as possible'. You'd see many a length of wire stretched on poles 'down the backyard' – or further. But not everyone these days has the room (or the neighbours) to allow this to happen. You need something smaller.

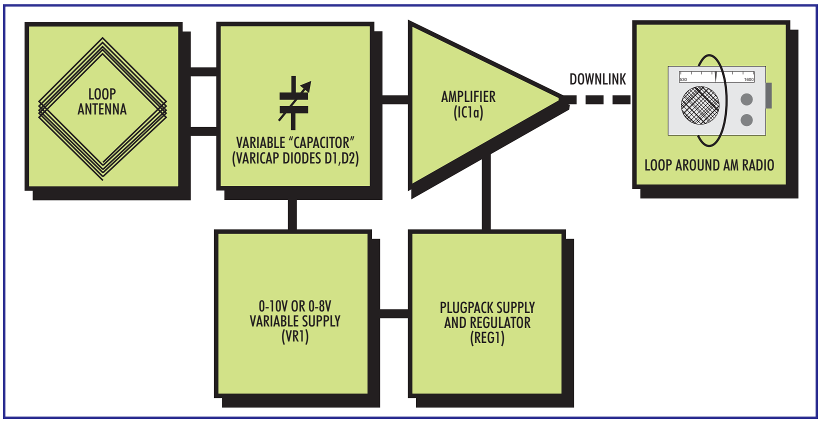


Fig.1: block diagram of the Active AM Loop Antenna. The first two blocks are connected in parallel to form a tuned circuit.

Back to the future

This project is specifically intended for those who want to listen to distant, weak or interference-prone AM radio stations, particularly those in the upper portion of the band. This tends to be where the weaker stations are located – most country commercial AM stations are about 2kW; some are even less. Compare that with city commercial stations or national broadcasting, which can be up to about 50kW.

We mentioned before that the aerial/antenna (let's standardise on the word 'antenna') can make a great deal of difference to the performance of a receiver.

Modern receivers are often quite reasonable in the selectivity and sensitivity department, so all that's left for us to play with is the antenna. Even if the receiver has provision for an external antenna and earth, you might be quite disappointed with the performance. That's because a random-length antenna is unlikely to be impedance-matched to the receiver and unlikely to be resonating anywhere near the required frequencies.

Loop antenna

A far better approach is to use the one we've gone for here – a loop antenna with an in-built amplifier. Moreover, a loop antenna exhibits reasonably good directivity – if you're trying to pick up a distant station and another station is swamping it, you can rotate the loop to 'null out' the unwanted one.

Coupling the loop antenna to the receiver is made simple because no physical connection is required. A second, single-turn loop couples the signal into the radio's in-built ferrite rod antenna. The distance between the loop antenna and the receiver can usually be as much as you require – up to several tens of metres, in fact.

Note: this project will NOT work on any AM radio which does not have an in-built ferrite rod antenna – this is the only way the received signal is coupled to the radio.

How it works

Take a look now at the block diagram (Fig.1). It shows the operation of the loop antenna.

Countless electromagnetic waves passing through the wire loops – generated by anything from lightning to electric motors to radio and television

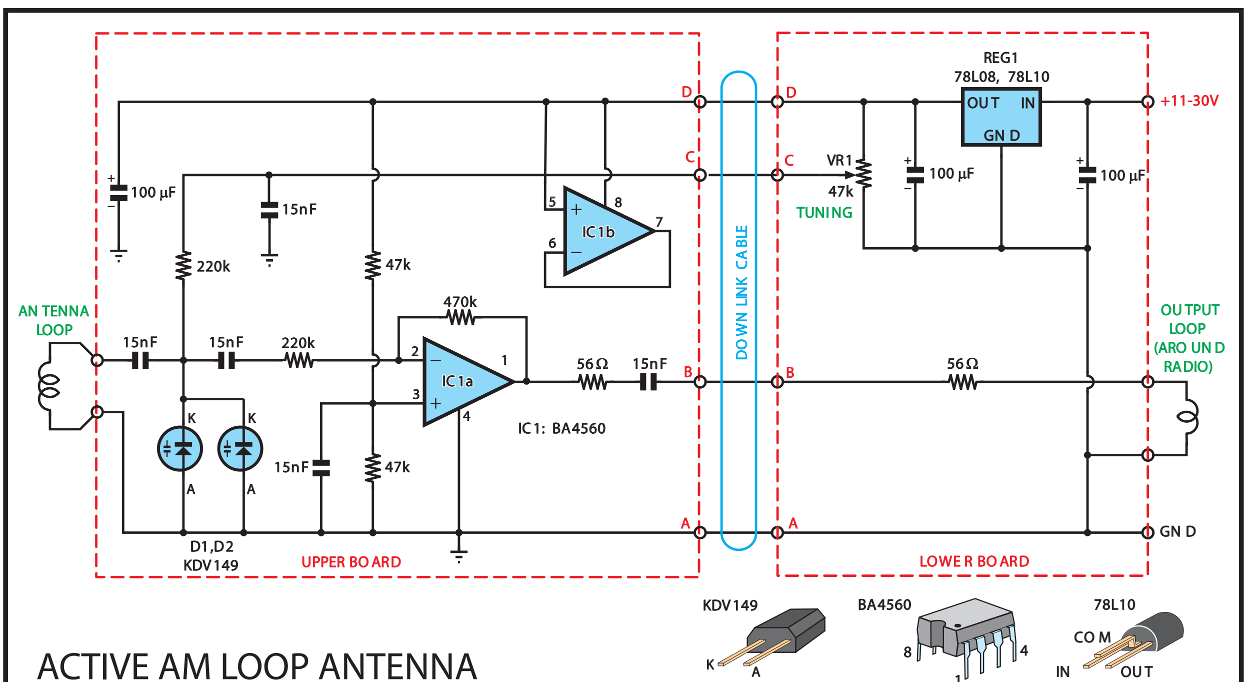
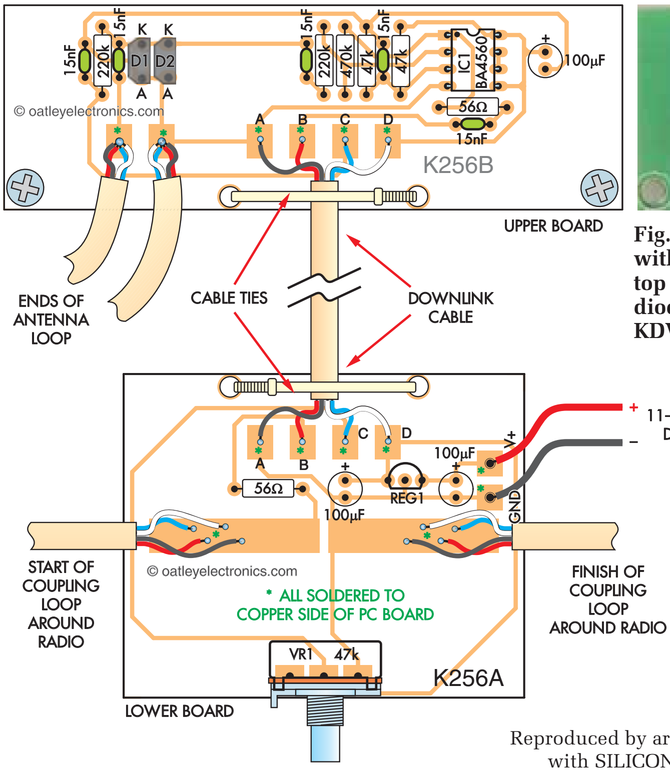


Fig. 2: the antenna loop picks up radio signals, which are then amplified and sent to an output loop, which re-radiates it into an AM radio receiver, via its internal ferrite aerial.



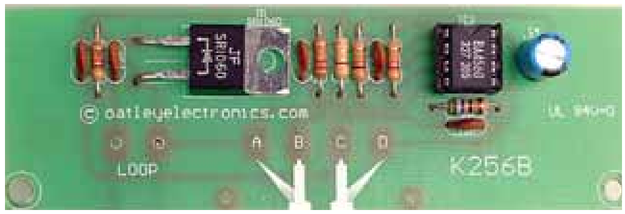


Fig.3: component overlays for the top and bottom PC boards, with their same-size photos alongside. Note that the prototype top (amplifier) board shown here used a single SR1060 Schottky diode in the tuning circuit, whereas the final version uses two KDV149 varicap diodes in parallel.

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stations – induce tiny electric currents at numerous frequencies.

The tuned circuit, consisting of X-frame-mounted coil loops, in parallel with a variable capacitance (we'll explain how this is achieved in a moment), effectively filters out almost all of these currents, except for the ones which correspond to the resonant frequency. The resulting narrow band of signals is then fed into an amplifier, based on op amp IC1a.

The amplified signals are then fed to another coil, this one designed to wrap around the AM receiver. This loop re-radiates the signal so that the ferrite rod aerial coil inside the radio can receive it again and process the signal, just as it would any other radio signal it receives.

What we are doing, therefore, is essentially 'preconditioning' the signal, so that the radio itself doesn't have to try hard to extract the wanted signal.

Remember those three things we mentioned earlier which determine a receiver's performance? Well, this circuit not only boosts the signal level, making the receiver more sensitive to weak signals, but also adds another stage of filtering, making the receiver more selective. As a result, the performance must be better – and in fact can be markedly better!

To keep interference to a minimum, the X-frame loop antenna itself should be mounted outside the home, well away from motors, switches or other sources of intereference.

Variable tuned circuit

As you probably know, you can make a tuned circuit's basic frequency variable by varying either the inductance or capacitance (remember that formula earlier?).

In general, it's a lot easier to adjust the capacitance, although many multi-band radio receivers do change coils (inductance) when switching bands.

We could use a small variable tuning capacitor, but these are not only hard to get, they're also getting rather expensive. The miniature ones commonly sold these days are incredibly fiddly to use and not at all conducive to tracking down weak radio signals!

But there is another way to obtain a variable 'capacitor'. Many semiconductors exhibit a change in capacitance when the voltage across them is changed. Varicap diodes are one such device, and in this circuit, we have

Modifications and an alternative antenna configuration

The original circuit (developed by Oatley Electronics) used a single SR1060 Schottky diode as the variable capacitance diode, and this covered just the 900kHz to 1600kHz end of the broadcast band. This device is shown in the photos, but was subsequently replaced by two KDV149 varicap diodes, enabling the entire broadcast band to be covered.

Note, if you don't want to build a large wooden antenna mast, you can achieve similar results by winding 10 turns of wire (spaced about 10mm apart) on a plastic hobby storage box (or crate) measuring about 350 × 350 × 260mm deep

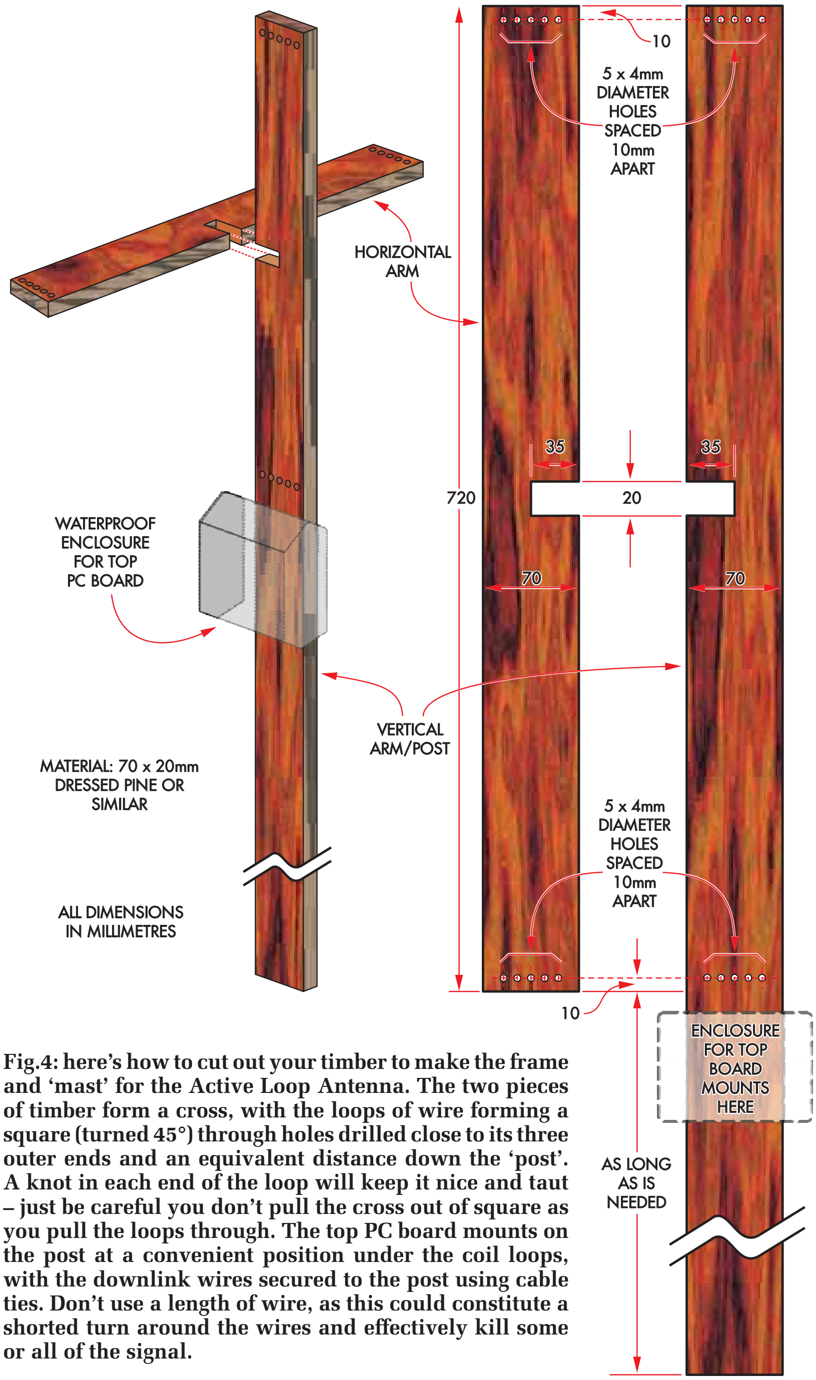


Fig.4: here's how to cut out your timber to make the frame and 'mast' for the Active Loop Antenna. The two pieces of timber form a cross, with the loops of wire forming a square (turned 45°) through holes drilled close to its three outer ends and an equivalent distance down the 'post'. A knot in each end of the loop will keep it nice and taut – just be careful you don't pull the cross out of square as you pull the loops through. The top PC board mounts on the post at a convenient position under the coil loops, with the downlink wires secured to the post using cable ties. Don't use a length of wire, as this could constitute a shorted turn around the wires and effectively kill some or all of the signal.

used two such diodes in parallel to achieve the required tuning range (ie, right across the AM broadcast band).

Circuit details

The complete circuit diagram for the *Active AM Loop Antenna* is shown in Fig.2.

The supply voltage for this project can be quite wide – from about 11V to 30V DC. A nominal 12V plugpack, for example, will usually give about 16V to 18V unloaded and would be fine.

This voltage is regulated to either 8V or 10V DC by REG1, depending on the regulator used (either a 78L08 or a 78L10). The resulting power rail supplies the amplifier IC directly and is also fed to a 47kΩ potentiometer (VR1). VR1's wiper (moving contact) is in turn connected to the cathodes (K) of the paralleled varicap diodes (D1 and D2) via a 220kΩ resistor.

At the top of its travel, the wiper will have the full 8V or 10V connected to the varicap diodes, while at the bottom, it will, of course, be near enough to 0V.

The antenna coil is coupled into the varicap diodes via a 15nF capacitor. This prevents the DC voltage, which is applied to the varicap diodes, from being shorted to ground via the quite low resistance of the antenna coil.

Similarly, the output from the tuned circuit is coupled to the input of op amp IC1a via another 15nF capacitor, so it cannot introduce DC into the amplifier circuit.

Finally, we should point out that only one of the two op amps in the BA4560 package is used. The other has one of its inputs connected to the positive supply and its other input to its output to ensure that it doesn't become unstable.

Construction

There are three parts to the construction of this project – two PC boards, plus the 'X'-shaped timber antenna support that houses the turns of telephone cable forming the antenna.

On one board, we have the amplifier section and the terminations for the loop antenna. The second board carries the power supply plus the connections for the loop to place around the AM radio receiver. Between the two boards is the downlink wiring.

Start construction by making your timber 'X' frame, using Fig.4 as a guide. You can use just about any scrap timber that you can find (but we wouldn't use Pyneboard or other composites if the antenna is to be erected out in the weather). Any timber used should have generous coatings of paint applied to weatherproof it.

Don't forget to drill all the holes for the 4-core telephone cable (antenna loop) before you glue and screw the sections together – it's a lot easier to drill flat timber!

Wind the five turns for the coil through the holes, starting with an outside hole closest to where the top PC board will be mounted – leave yourself about 200mm or so of cable to work with past the position where the PC board goes. Tie a single-loop knot in the cable as it passes through the first hole.

Continue to pass the cable through the other three outside holes, then the next across, and so on until the coil is complete. As you go, keep the turns of the coil nice and taut but not so taut as to pull the timber out of the 'X' shape.

When completed, tie a single-loop knot in the last hole so that it keeps the wire loops taut. Again, leave yourself 200mm or so of cable underneath where the PC board will mount, and then cut the remainder off. Hang onto that – you'll need it shortly for the downlink!

Parts List – Active Loop Antenna

*1 PC board, code 813 (Ant Loop) 31mm × 94mm
*1 PC board, code 814 (Rad Loop) 58mm × 48mm
1 Weatherproof plastic box (eg Oatley HB4)
1 30 × 54 × 83mm plastic box
1 8-pin IC socket
* Available from the *EPE PCB Service*

Semiconductors
1 BA4560 dual op amp (IC1)
1 78L08 or 78L10 voltage regulator (REG1)
*2 KDV149 varicap diodes (D1, D2)

Capacitors
3 100µF 16V electrolytic
5 15nF disc ceramic

Resistors (0.25W 5%)

1 470kΩ	(code yellow purple yellow gold)
2 220kΩ	(code red red yellow gold)
2 47kΩ	(code yellow purple orange gold)
2 56Ω	(code green blue black gold)

1 47kΩ linear potentiometer (and knob to suit).

Miscellaneous (not included in Oatley Electronics kit)
Timber, screws and mounting hardware as required
40m of 4-wire telephone cable or equivalent

PC board construction

The printed circuit boards component layouts and interwiring are shown in Fig.3. These two boards (together with two Varicaps) are available as a pair from the *EPE PCB Service*, codes 813 (Ant Loop) and 814 (Radio Coupling).

It doesn't matter which board you start with – both are quite simple and should only take an hour or so to complete. On the loop antenna board, the only polarised components are the amplifier IC, the electrolytic capacitor alongside it and the varicap diodes.

Start by installing the smallest components – the resistors and non-polarised capacitors, then install the semiconductors and the electrolytic capacitor. Don't worry about the loop or downlink wiring at the moment.

On the power supply board, three of the five components are polarised, so make sure you get them in the right way. The potentiometer will only go in one way (otherwise the shaft points inwards).

Loop and downlink wiring

In the prototype, 4-wire telephone cable was used because this happened to be on hand – even though the loop antenna does not use the four individual wires (however, the downlink does).

Therefore you could just as easily use single-conductor wire for the loop if you wished. Note that telephone cable is quite a lot tougher than single wire and so offers some protection from, for example, birds sitting on it or even pecking at it!

If you use telephone cable for the loop antenna wiring, simply connect all four wires in parallel as you solder them to the PC board. The same applies for the output loop – the one which goes around your radio. The wires can be twisted together to make this easier. Note that all connecting wires solder to the pads on the underside of the PC board.

You might be wondering why each single wire of the telephone cable was not connected in series with its mate and terminated as such on the PC board. Wouldn't this create a significantly greater inductance (ie, four times greater)?

Oatley Electronics originally had exactly the same idea. Unfortunately, when they tried it out, they found that the capacitance of the closely-spaced wires within the cable started to create its own problems.

They found that by paralleling all four wires in the cable, this problem was eliminated. More importantly, they found that the overall performance of the antenna was better!

In the downlink, all four wires in the telephone cable *are* used independently and are connected to the points A, B, C and D on the PC boards.

With coloured wiring in the cable (black, red, blue and white), it's not easy to get it wrong!

This downlink wiring can be quite long – the prototype had 20m between the two PC boards, and there didn't appear to be any loss of signal compared to a 5m separation. If you need more distance, give it a go – you have nothing (except signal) to lose.

In use

If possible, make a complete turn around the radio receiver with the output loop (remember, the radio *must* have a ferrite rod for this antenna to work). How do you know if it has a ferrite rod antenna? If you can turn it on and it works without anything connected, it's a pretty fair bet that it has one. Virtually all small AM radios have a ferrite rod antenna inside.

Tune the radio to the weak station you want to listen to. Now adjust the potentiometer slowly – at one point, you should find a significant increase in the level of that station (or a decrease in any other stations that are interfering with it).

Also, recall what we said before about the antenna being able to turn so that it faces the wanted station – by facing, we mean broadside on, or if you take a line across the X frame the wanted station should be perpendicular to that line.

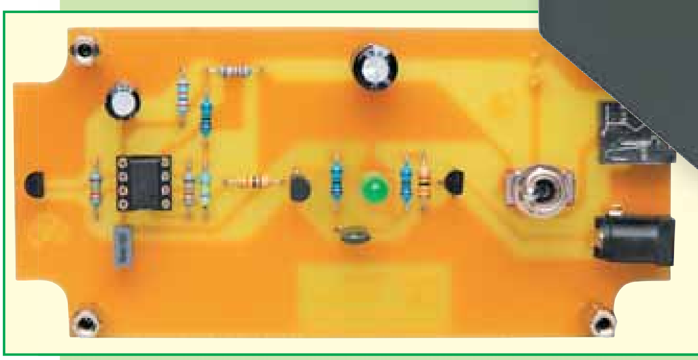
The antenna will work equally well from both sides. However, if you turn the antenna through 90°, you should find that its performances decreases significantly. Conversely, any other stations that are now broadside-on will be much better. ***EPE***

WHERE FROM, HOW MUCH?

This project was designed by Oatley Electronics who retain the copyright.
A kit for this project (K256), which includes both PC boards, on-board components and cases (as listed above) is available from Oatley Electronics, for about £15. The kit does not include the 4-wire telephone cable nor any timber or mounting hardware.
Contact Oatley Electronics via their website: www.oatleyelectronics.com

A Beam-Break Flash Trigger

By JIM ROWE



Here's an easy-to-build accessory for the Time Delay Photoflash Trigger described in our February 2011 issue. It triggers the delay unit and your photoflash in response to an object interrupting an invisible beam of infrared (IR) light. Alternatively, it can be used on its own to directly trigger a photoflash.

A FEW months ago (in February 2011), we described a *Time Delay Photoflash Trigger*. This unit was triggered by a sudden sound picked up by an electret microphone insert. It then immediately opened the camera's shutter and then fired the photoflash shortly after, depending on the delay period programmed into the unit.

Using sound pick-up in this manner is a popular and effective method of triggering a flash for 'stop motion' and other kinds of special effects photography. However, in addition to the electret mic input, we also gave the delay unit a second 'contact closure' input, so that it could be triggered using other techniques. Which was just as well, because as soon as the delay unit was published, we started getting requests for a light beam trigger.

Flash trigger

This simple *Beam-Break Flash Trigger* is the result of those requests. It's mainly intended as an alternative triggering front-end for the Time Delay Photoflash Trigger and is connected to the latter's 'contacts' input. However, it can also be used to trigger a photoflash unit directly if you don't need the programmable time delay capabilities.

Note, however, that using the unit to directly trigger the flash has one important limitation. Unlike the Time Delay Photoflash Trigger, it doesn't also trigger the shutter. This means that you have to open the shutter manually before the infrared beam is interrupted (eg, at night or in a darkened studio).

This new project is in two parts: (1) an IR Source unit, which produces the IR beam and (2) a Detector unit, which monitors the IR beam and closes its output trigger contacts briefly if the beam is interrupted. These two units are linked with an interconnecting cable, which supplies the Source unit with power.

If you're already wondering how you accurately line up the Source and Detector units when the IR light beam is invisible to the human eye, wonder no more. That problem has been solved by providing the detector unit with a visible green LED, which lights when the IR beam is being received. This makes the lining-up process easy.

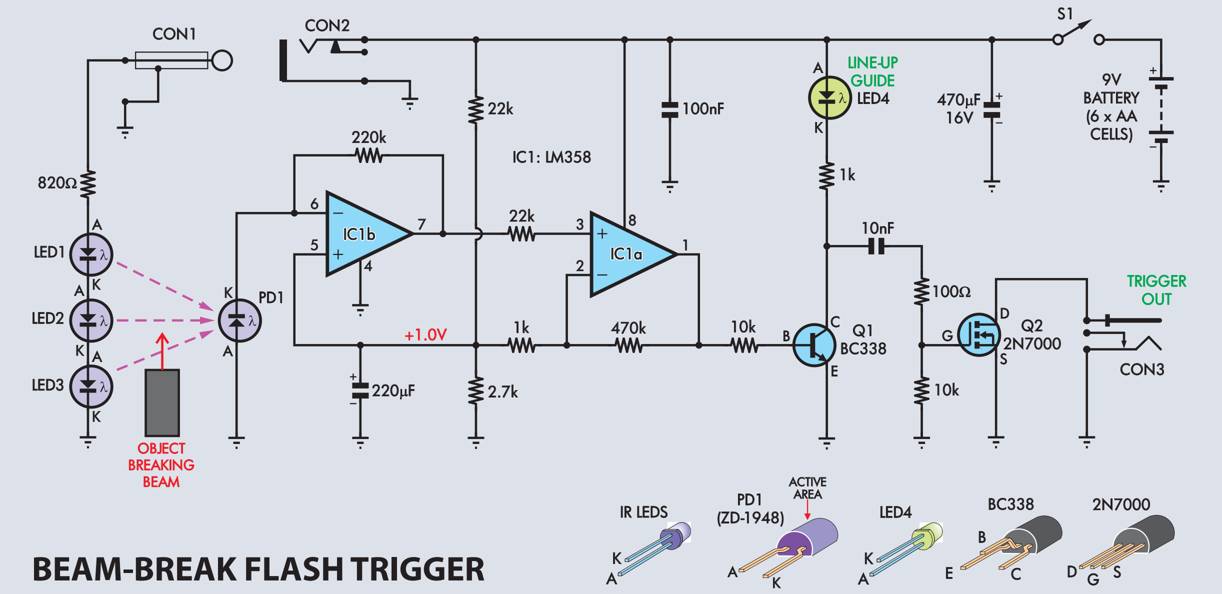


Fig.1: the infrared beam is generated by LED1 to LED3 and picked up by photodetector diode PD1. Op amp IC1b functions as a current-to-voltage converter, while IC1a is wired as a non-inverting amplifier. The latter drives transistor Q1 and MOSFET Q2 to briefly switch the trigger output when the IR beam is interrupted.

Both parts of the project run from a 9V battery fitted inside the Detector unit's box. The total current drain is about 15mA, which means that the battery should be either a set of six AA (1.5V) alkaline cells or a single high-energy 9V lithium battery. A standard 9V zinc-carbon or alkaline battery is not up to the job, as its life would be too short.

Circuit details

The complete circuit diagram for the *Beam-Break Flash Trigger* is shown in Fig.1. There's really not a great deal in either part of the circuit. In fact, the IR Source unit is nothing more than three IR LEDs connected in series, plus an 820Ω series resistor. This resistor limits the current from the 9V supply (and thus the current through the IR LEDs) to about 7.5mA.

Power is derived from the battery in the Detector unit via a cable fitted with a 3.5mm jack plug (CON1). This mates with CON2 on the detector unit.

In the Detector unit, the IR beam from the Source unit normally falls on PD1, an IR photodetector diode. This photodetector is connected between ground and the inverting input (pin 6) of op amp IC1b (an LM358).

Op amp IC1b is connected as a current-to-voltage converter. Its pin 7 output sits somewhere between +1.7V and +4.0V when the IR beam is present, but rests close to +1.0V when no IR light is falling on PD1. This 'dark' output voltage of +1.0V is basically set by the voltage divider formed by the 22kΩ and 2.7kΩ resistors, with the 220µF capacitor providing filtering. This is used to directly bias pin 5 of IC1b and to bias pin 2 of IC1a via a 1kΩ resistor.

The output at pin 7 of IC1b is fed to the non-inverting input (pin 3) of IC1a, which is configured as a non-inverting amplifier with a voltage gain of 471. Because of this very high gain, IC1a acts very much like a comparator. Its pin 1 output sits at over +8V when the IR beam is present, but falls to 0V when there is no IR light falling on PD1 (ie, the IR beam is interrupted).

IC1a's output in turn drives the base of transistor Q1 via a 10kΩ resistor. As a result, Q1 is turned on or off depending on whether the IR beam is present or not. When the IR beam is present, Q1 is on and when the beam is interrupted, Q1 turns off.

LED4 and its series 1kΩ resistor form the collector load of Q1. This means that LED4 lights when Q1 is on and turns off when Q1 is off. This allows LED4 to be used as a guide when lining-up the Source's IR beam with PD1, as described previously.

Switching the trigger output

Because Q1 is switched on when the IR beam falls on PD1, its collector voltage is normally held down to about 0.4V. However, if the beam is interrupted, Q1 turns off and its collector voltage rises to nearly +9V.

This sudden voltage change is used to switch on Q2, a 2N7000 MOSFET, which is used as an output switch across triggering output CON3. As shown, a 10nF coupling capacitor and Q2's 10kΩ gate resistor form a simple differentiating circuit. This results in Q2 being switched on only briefly when Q1's collector voltage rises when the beam is interrupted. The 100Ω resistor in series with the coupling capacitor is there to suppress any possible oscillation during switch-on or switch-off.

That's about it, apart from power switch S1 and the 470µF and 100nF capacitors, which decouple the supply rail voltage to keep it constant. The current drain of the detector circuit varies between about 7.5mA when the IR beam is present and 1.5mA when it is interrupted, so the total battery drain for both sections varies between 15mA (beam present) and 9mA (beam interrupted).

Parts List

IR Source Unit

- *1 PC board, code 808, size 57mm × 26mm
- 1 UB5-size box, 82mm × 53mm × 31mm
- 4 6mm long untapped spacers
- 4 M3 × 12mm screws, countersink head
- 4 M3 hex nuts
- 1 nylon cable tie, 75mm long
- 1 2m length of figure-8 cable
- 1 3.5mm mono jack plug, cable type (CON1)
- 3 5mm IR LEDs (LED1 to LED3)
- 1 820Ω resistor

Detector Unit

- *1 PC board, code 809, size 122mm × 58mm
- 1 UB3-size box, 129mm × 68mm × 44mm
- 1 SPDT mini toggle switch (S1)
- 1 PC-mount 3.5mm stereo jack socket (CON2)
- 1 PC-mount 2.5mm concentric power plug (CON3)
- 4 M3 × 15mm tapped spacers
- 8 M3 × 6mm machine screws, pan head
- 2 1mm PC board terminal pins
- 1 9V battery clip lead
- 1 8-pin DIL IC socket
- 1 30mm length of 12mm to 15mm diameter black PVC conduit or brass tubing
- 1 piece of IR-transparent red film, approx. 16mm square
- 1 9V battery snap connector OR 1 x 4-way AA cell holder plus 1 x 2-way AA cell holder

Semiconductors

- 1 LM358 dual op amp (IC1)
- 1 BC338 *NPN* transistor (Q1)
- 1 2N7000 *N-channel* MOSFET (Q2)
- 1 IR photodetector (PD1) (Jaycar ZD-1948 or similar)
- 1 5mm green LED (LED4)

Capacitors

- 1 470µF 16V radial elect.
- 1 220µF 16V radial elect.
- 1 100nF metallised polyester
- 1 10nF metallised polyester

Resistors (0.25W 1%)

1 470kΩ	1 2.7kΩ
1 220kΩ	2 1kΩ
2 22kΩ	1 100Ω
2 10kΩ	

* Available as a pair from the *EPE PCB Service*

The IR Source board carries the three infrared LEDs (LEDs1-3) plus an 820Ω current-limiting resistor. It's mounted inside a UB5 case on 6mm untapped spacers and derives its power from the Detector unit.

Construction

You can see from the photos that the two units which make up the Beam-Break Flash Trigger are each housed in a small plastic box. The IR Source circuit is built on a small PC board coded 808 (57mm × 26mm), while the Detector parts are installed on a larger PC board coded 809 (122mm × 58mm). These boards are available as a pair from the *EPE PCB Service*.

Start the assembly by building the IR Source board – see Fig.2. This should take you just a few minutes, since there are only four components to install – the three infrared LEDs and the 820Ω current-limiting resistor.

Be sure to orient the three IR LEDs correctly, as shown in Fig.2. **In addition, these three LEDs must be fitted with their leads bent down by 90°, so they face out of the end of the box when the board is mounted inside.**

In particular, note that the centre LED (LED2) is fitted with its body relatively low down near the board, while the two outer LEDs are fitted higher and with their leads bent inwards towards LED2. This is done so that they form a triangular group, to provide a relatively compact beam source (see photo above).

Once these parts are in, install the power cable by soldering its leads to the +9V and 0V pads. The cable is then anchored using a small nylon cable tie that passes through the two 3mm holes on either side.

Having completed the board, it can be mounted inside its plastic box on four 6mm untapped spacers, and secured using four M3 × 12mm countersunk head screws and nuts. As shown in the photos, the IR LEDs face outwards through a 10mm hole in one end of the box, while the power cable exits via a small notch filed in the top at the opposite end. Fig.3 shows where to drill the holes in both boxes.

Finally, complete the IR Source unit by attaching the front panel label to the lid. A full-size artwork is shown

Table 1: Resistor Colour Codes

No.	Value	4-Band Code (1%)	5-Band Code (1%)
1	470kΩ	yellow violet yellow brown	yellow violet black orange brown
1	220kΩ	red red yellow brown	red red black orange brown
2	22kΩ	red red orange brown	red red black red brown
2	10kΩ	brown black orange brown	brown black black red brown
1	2.7kΩ	red violet red brown	red violet black brown brown
2	1kΩ	brown black red brown	brown black black brown brown
1	820Ω	grey red brown brown	grey red black black brown
1	100Ω	brown black brown brown	brown black black black brown

An infrared transparent filter is fitted to the inside of the case at the receiving (PD1) end of the UB3 box, while a 30mm × 12mm-diameter 'light-hood' (eg, brass or plastic tubing) is attached to the outside of the case.

Follow this photo and the parts layout diagram Fig.2 to build the Detector PC board.

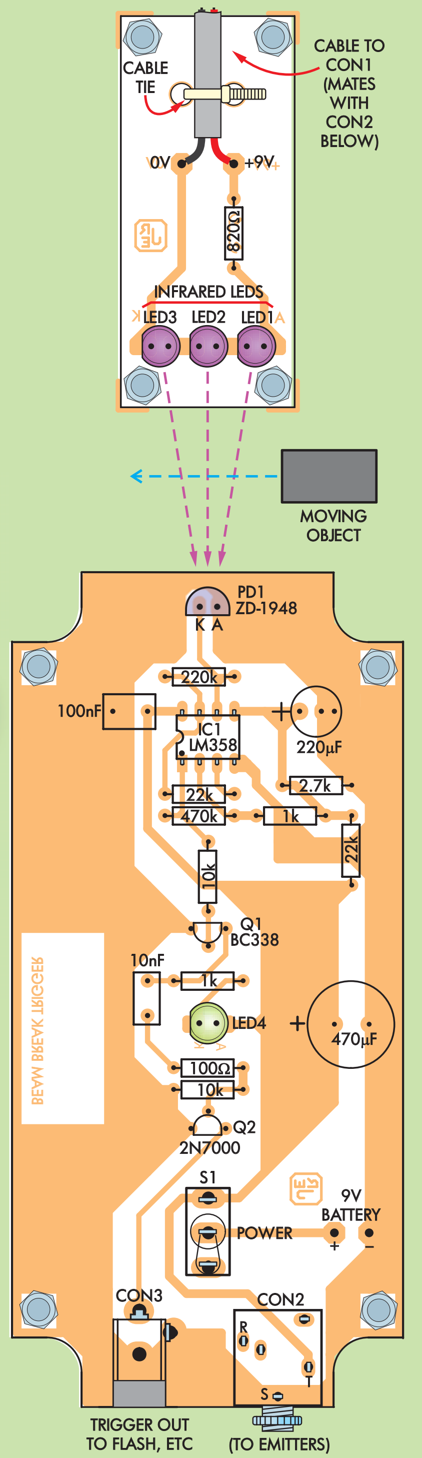


Fig.2: install the parts on the two PC boards as shown on this layout diagram. LED4 (green) on the Detector board is mounted vertically, but be sure to bend the leads of IR LED1 to LED3 through 90° before installing them on the IR Source board – see text and photo.

in Fig.3. A photocopy can be taken and cut out and glued on the case lid.

Detector board assembly

There are more components on the Detector board, but its construction is still straightforward – see Fig.2. Install the resistors first, taking care to use the correct value at each location. Table 1 shows the resistor colour codes, but it's also a good idea to check each one using a digital multimeter before soldering it in place.

Follow these parts with the metallised polyester capacitors, then fit the two electrolytic capacitors. The latter are polarised, so be sure to orient them as shown. Next, the two PC board terminal pins, used to make the battery connections, can be fitted. **Note that both pins are fitted on the copper side of the board, to make it easier to solder the battery clip leads to them.**

Switch S1 and connectors CON2 and CON3 are next on the list, followed by an 8-pin socket for IC1. Be sure to orient the socket with its notched end towards the adjacent 100nF capacitor, to guide you when plugging in IC1 itself later on.

Transistor Q1, photodetector PD1, MOSFET Q2 and LED4 can now all go in, again taking care to orient them correctly. Note that PD1 is mounted vertically with its curved side facing outwards, and with the centre of its body about 5mm above the PC board. LED4 should also be mounted vertically, with the bottom of its body about 12mm above the board (this ensures that it will protrude slightly from its matching hole in the box lid after assembly).

The Detector board can now be completed by plugging IC1 into its socket (take care with the orientation).

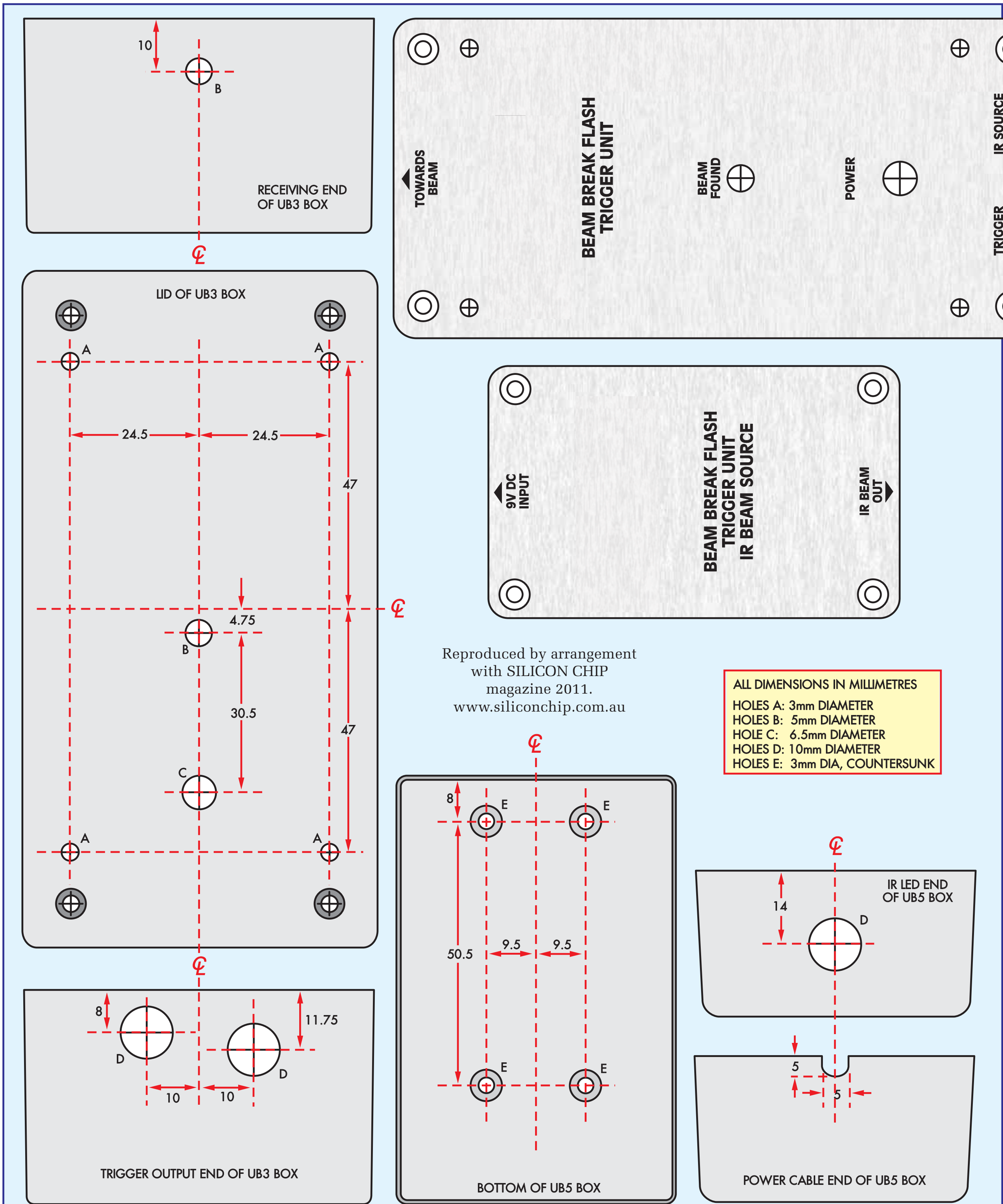


Fig.3: these drilling diagrams for the UB3 and UB5 boxes can be copied and used directly as templates, or you can mark the holes out manually using the measurements indicated. Also shown are the two front panel artworks. They can be photocopied, cut out and glued on the boxes.

The detector board is then ready to be mounted behind the lid of the UB3-size plastic box.

The first step is to drill and ream out the various holes in the lid and ends of the box, as shown in Fig.3. That done, fit a photocopy of the front panel label and cut out the holes using a sharp hobby knife, then secure the board to the lid using four M3 × 15mm tapped spacers and eight M3 × 6mm machine screws.

Note that you'll need to remove the upper nut from the ferrule of switch S1 before doing this, so the ferrule can pass up through its matching hole in the lid. Once the board is in place, the nut can be replaced and threaded down against the top of the lid. The lower nut and lockwasher can then be threaded up against the underside of the lid, using a small spanner.

The next step is to fit a small square of red 'IR transparent' film inside the box behind the single 5mm hole at the IR photodetector diode PD1 end. It can be held in place using a couple of narrow strips of transparent tape, one on either side.

A short 'light hood' is now attached to the photodetector (PD1) end of the box. This must cover the 5mm hole and be as close as possible to concentric with it.

The hood itself can be fashioned from a 30mm length of 12mm diameter brass tubing (see photos) or from a similar length of opaque (preferably black) PVC conduit. Whichever you use, it's simply glued to the end of the box using five-minute epoxy cement.

Now for the final assembly. First, solder the battery-snap leads to the terminal pins on the underside of the board, then place the battery in the bottom of the box and fasten it in place using either a small aluminium 'U' bracket or a strip of gaffer tape. Finally, lower the lid and PC board assembly into the box before fitting the screws to hold everything together.

Above: the Detector board is secured to the lid of the UB3 case using four M3 x 15mm tapped spacers and eight M3 × 6mm machine screws

Left: a 'light hood' is fitted to the end of the Detector unit to prevent interference from stray IR light sources.

Trying it out

No adjustments are required, so you can try it out simply by plugging the power cable from the IR Source into CON2 on the Detector unit and turning on power switch S1.

If the Detector's light hood is now aligned with the output from the IR Source (or any other source of IR radiation), LED4 should immediately begin glowing. If it does, block the end of the hood with your thumb or a small piece of opaque material and check that the LED immediately switches off.

The same thing should happen if you turn the IR Source away from the Detector, or if you simply block the beam with your hand or some other small opaque object. If this happens, then your Beam-Break Flash Trigger is probably working correctly and is ready for use.

If you're going to be using it in conjunction with the Time Delay Photoflash Trigger unit, all that remains is to make up a suitable cable to connect the two together. This simply involves connecting the Detector's trigger output to the 'external trigger contacts' input (CON4) of the delay unit.

The Beam-Break Flash Trigger should give reliable triggering with the IR Source unit placed up to a metre or so from the Detector box in normal room lighting. This 'beam length' range can be extended considerably in dark (eg, night-time) conditions, but in bright sunlight it will be shortened due to the relatively high level of IR in the ambient light. ***EPE***

Direct flash triggering: making the cable

As mentioned in the article, the Beam-Break Flash Trigger can also be used to trigger an electronic flash directly, rather than via the Time Delay Photoflash Trigger. To do this, trigger output CON3 is simply connected to the photoflash via a suitable cable.

However, when you're making up this cable, make sure that the positive side lead from the flash input is connected to the centre contact of the plug that goes to CON3. If the polarity is reversed, MOSFET Q3 in the Beam-Break Flash Trigger could be damaged.

The procedure is to first use your DMM to check the polarity of the voltage at the end of the cable that's plugged into the flash unit (ie, with the flash unit powered up and ready for triggering). Once that's done, you'll then know which way round to connect the cable to the plug that goes to CON3 on the Detector unit.

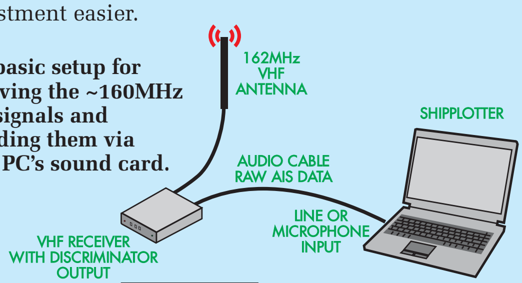
While you're checking the polarity of the cable leads, make a note of the actual voltage itself. If it is below 60V, that won't be a problem. Conversely, if it's higher than 60V, you'll need to replace the 2N7000 MOSFET with one having a higher voltage rating – such as an IRF540N.

CONVERTING UNIDEN SCANNERS FOR AIS

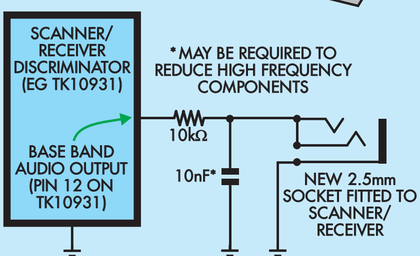
THESE well-priced, wide-coverage and very popular handheld scanners offer a valuable 'close call' feature and have become well respected for general VHF/UHF work.

The discriminator tap access is straightforward and fitting an external socket should make for a neat and professional enhancement to the set. However, your scanner warranty may become invalid!

All variants of the UNIDEN UBC72/73 and 92/93 use the 24-pin TOKO TK10931 discriminator IC, with baseband audio output at pin 12 (LND7). This accesses the unfiltered audio. A resistor soldered to a convenient pad on the PC board provides the tap without otherwise affecting scanner operation. In most cases, a 10kΩ resistor suffices, but with some sound cards we've had to go as high as 220kΩ to avoid overload. You could also use a 220kΩ trimpot in series with a 10kΩ resistor to make adjustment easier.



The basic setup for receiving the ~160MHz AIS signals and decoding them via your PC's sound card.



Tapping into the receiver's unfiltered audio is quite simple. At right is the circuit diagram suiting the Uniden scanner.

The resistor's other end is wired to a 2.5mm mono chassis socket mounted on the back of the scanner. There is sufficient space between the stacked PCBs and case for this.

A short wire for the ground lead can be run to the antenna's ground terminal – a 10nF capacitor between the resistor's far end and ground may help remove residual higher frequency portions.

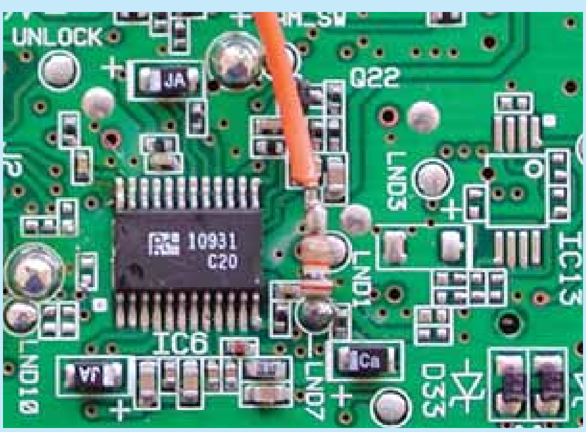
A 2-wire external lead then connects to a stereo 3.5mm plug to suit the PC soundcard's line-in or mic input socket. The scanner squelch must be wide open ('hissing') but the scanner's internal speaker volume can be turned right down.

The antenna

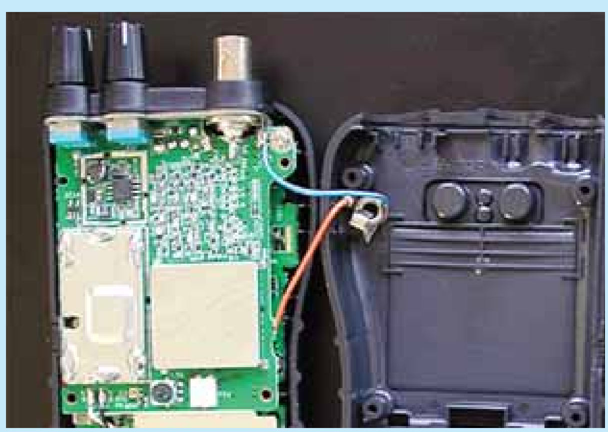
Unlike 2.4GHz WiFi, VHF marine signals are not *so* influenced by nearby obstructions, but the best AIS reception will still be gained with clear line-of-sight (LOS) coverage.

The supplied 'rubber ducky' whip antenna on most scanners should allow open-terrain AIS reception to perhaps 6nm (nautical miles) (~10km), but either elevation or a better antenna (or both) will greatly assist – it really depends on your proximity to nearby shipping.

The BNC socket on most scanners readily allows modest coax runs to rooftop Yagi beams, but a simpler and more portable antenna may be better – especially if AIS signals come from a wide arc.



Undoing six Philips-head screws readily dismantles the Uniden scanner and the revealed circuit boards simply clip apart. Neatly solder the 10kΩ resistor and outlet wire at LND7, perhaps sliding fine heat shrink tubing over the wire joint to prevent circuit board shorts.



To prevent confusion with the scanner's fitted 3.5mm headphone socket, the output socket to the computer sound card should be an open-type 2.5mm mono socket (eg, Jaycar PS-0105), as modern enclosed types are slightly too long for the most suitable rear case hole position.

. . . and a cheap 'Slim Jim' antenna to make

By Stan Swan

A DIY 'Slim JIM'

One of the most appealing antennas for such work is the so called 'Slim Jim' (an acronym for 'J-type Integrated Match') – invented in 1978 by the late Fred Judd, G2BCX.

Any parallel conductors could be used (some diehards swear by HO-scale model train track!), but such an antenna can be quickly and cheaply made from a length of 300Ω impedance TV ribbon.

This is becoming rather difficult to get, having largely given way to 75Ω coaxial cable (which is, of course, entirely *unsuitable*).

Although cheap, this ribbon rapidly deteriorates in the wind and sun if left unprotected, so housing inside a vertically supported plastic conduit (eg, mains conduit) is almost essential for outside use. Plastic conduit will not degrade performance at all.

Considerable variation on the basic design can be tolerated, as aspects such as the gap space, conductor spacing, velocity factor (VF) of the wire and even nearby metallic objects influence performance.

At 162MHz, an open-space wavelength = speed/frequency = 3 x 10^8/1.62 x 10^8 = 1850mm. However, slower signals within the TV ribbon decrease this by ~0.9 (known as the velocity factor) giving a working AIS wavelength of 1665mm.

The Slim Jim is ¾-wavelength long (although only the upper half-wave portion receives), so a 1250mm antenna length should suffice. 'Cut and try' experimentation is encouraged – cut slightly longer initially and trim to suit for best performance.

Almost any TV-grade (ie 75Ω) coax suits Slim Jim connection to the VHF receiver's BNC antenna socket, and use of light-grade flexible coax makes a roll-up version feasible.

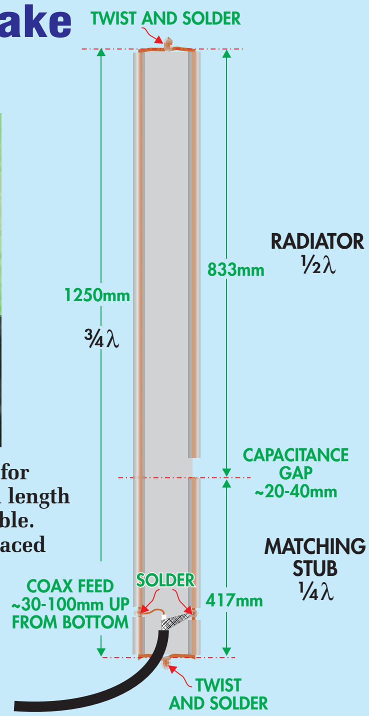
Unless you're making a very long run from antenna to receiver, losses should not be too much of a problem. Of course, if your run is long (ie, greater than, say 10m), go for one of the better (low-loss) cables.

To construct a Slim Jim, simply follow the diagram at top right. You'll need a length of ribbon cable about 1280mm long, to allow the two ends to be stripped and shorted, as shown.

The wires at each end of the cable are bared, twisted together and soldered (don't ignore the last part, especially if you are going to erect the antenna outside). In fact, a short length (30mm or so?) of heatshrink tubing over each end will further protect the copper wire from corrosion.

The exact position for the coax feed connection is not all that important for a receiving antenna – between 30 and 100mm up from the bottom is the range. The centre wire of the coax is soldered to the 3/4 wavelength side (don't cut the wire, just remove the insulation) while the braid connects to the matching stub opposite the centre wire connection point.

The capacitance gap, on the 'earthy' side only, can be anywhere from about 20mm to 40mm. Don't simply cut the cable; the short length of wire needs to be removed.



A 'Slim Jim' antenna for 162MHz made from a length of 300Ω TV ribbon cable. This would best be placed inside a length of plastic conduit and mounted outside, as high as possible and away from metal (such as a mast or roof).

Apart from putting it inside a suitable length of conduit (say 1.3m) with a plug on the top end (the bottom end could be filled with silicone sealant to stop insects and spiders calling the Slim Jim home), your antenna is now complete and ready for use.

Slim Jim low angle performance is legendary, as the design best handles signals received near parallel to the ground – forget it for near-overhead aircraft and satellites!

Unless you're tracking flying boats (or live on a hilltop), vessels are naturally going to be near-horizontal anyway. Slim Jim AIS reception out to 20nm (~30km) could be expected when the antenna is well elevated, perhaps by being hoisted up a tree (inside a conduit) with a nylon line.

Stan, monitoring at Eastbourne (green symbol) tracks two vessels using VHF radio AIS into and out of Wellington harbour. This gives a good idea of the type of performance to expect using the modified scanner and Slim Jim antenna described here and AISMon software running on your PC.

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PCB Track Probing unit – *On track*

I RECENTLY purchased from *EPE* the Version 3 PICmicro MCU development board. Unfortunately, this unit comes without any instructions, circuit diagram or even block diagram. As I wish to use this versatile looking piece of equipment to develop PIC circuits of my own design, I needed to ascertain where connectors and plugs and sockets were connected in the circuit.

I have used the idea I am about to describe many times before in lash-up form, but felt that I ought to make this one as a completed unit, calibrated and mounted in a convenient box and having suitable probes. I then realised that it could be of interest to other readers of *EPE*, hence this letter/IU.

On track

The requirement was to be able to trace printed circuit tracks between components, IC pins, and sockets, even while components populate the PCB, but without power being connected. This probing should not cause any junctions that are connected between the probes to turn 'on' and should show unambiguous connections, while possibly being able to measure track resistance at the same time.

The finished circuit will allow the measurement of resistance, up to two hundred ohms in my case. This figure could be changed if required, but for my intended use this is adequate. If a track reading is below the calibrated set point on the dial, an audible sound is heard.

Circuit details

I decided to use a low voltage of about 0.3V to power the probes, and a variable trip point on a comparator to sense the connections and its resistance between pins and tracks. The low voltage is derived by using a resistor chain from both the positive supply and also the negative supply (a single 9V battery) with a 1N4002 'dropper' diode, as may be observed from the circuit diagram Fig.1.

As the circuit around the 'dropper' diode is a DC Wheatstone bridge, the trip point could be used to infer low values of resistance of track. The bridge detector is the high gain (open loop) differential circuit, the output of which triggers an audible warning output stage.

The circuit is powered with a single 9V battery. The low probe voltage is derived from the voltage drop across D1, a 1N4002 silicon rectifier. It is tapped down using a couple of 1.5kΩ resistors in the upper arms, and 1kΩ in the lower arms, with a 250Ω variable resistor (pot.) shunting one of the arms as shown. The probes connect across the other lower arm. These resistors form the Wheatstone bridge circuit, with the probe as the unknown value.

When the 'test' PCB is probed, if track exists between the probe points, then the voltage across the probe falls, depending upon the resistance of the track. This drop in voltage is sensed by a comparator (IC1a) with an adjustable reference voltage, also derived from the potted down voltage from the D1.

The output from the comparator turns on an oscillator (IC1b) driving a piezo sounder. I use an audible warning instead of an LED, as this means that I do not have to switch my eyes back and forth while probing. By adjusting the trip point, an indication may be had of the resistance of the track, in the classic Wheatstone bridge manner. In a normal Wheatstone bridge a null indicator is used, but this unit uses a 'go-nogo' indication, or high/low change at the resistance

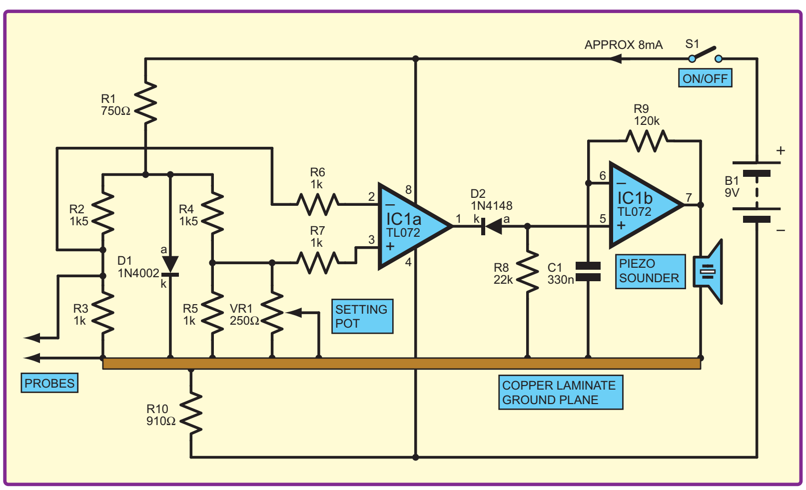


Fig.1. Circuit diagram for the PCB track probe

value across the probes. An audible output indicates track resistance below the Setting Pot calibrated value, while no audible output indicates high resistance between the probes.

I made my probes using two largish sewing needles soldered to the probe wires, and mounted with hot melt glue inside two old Biro cases, cheap as chips!

Calibration and construction

Calibration may be done using a number of known low value resistors in series, adjusting the trip at each point to trigger the acoustic sounder, and marking the panel accordingly. Of course, this Wheatstone bridge method is used in old fashioned instruments to determine resistor values very accurately, but my requirement here is only to a few percent in resistance value at best. My unit works very well.

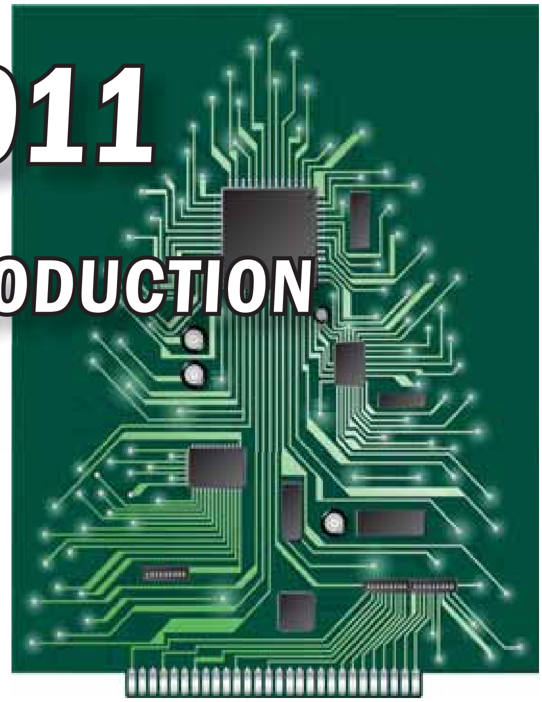
I made my unit using a form of construction that I favour for prototype and one off construction. This uses copper laminate as a base and 'ground' connection, and gluing on pieces of stripboard, cut to suitable size and shape to mount IC's and other components.

It is similar to 'ugly' construction, but I find it easy and convenient, even when cannibalising old prototypes on stripboard that I have made over the years, to supply the small pieces of board required, so the cost is quite low.

Ivan J Eamus, Rutland

TEACH-IN 2011

A BROAD-BASED INTRODUCTION TO ELECTRONICS



Part 9: Digital-to-Analogue and Analogue-to-Digital Conversion

By Mike and Richard Tooley

Our Teach-In series is designed to provide you with a broad-based introduction to electronics. We have attempted to provide coverage of three of the most important electronics units that are currently studied in many schools and colleges in the UK. These include Edexcel BTEC Level 2 awards, as well as electronics units of the new Diploma in Engineering (also at Level 2). The series will also provide the more experienced reader with an opportunity to 'brush up' on specific topics with which he or she may be less familiar.

Each part of our Teach-In series is organised under five main headings; Learn, Check, Build, Investigate and Amaze. Learn will teach you the theory, Check will help you to check your understanding, and Build will give you an opportunity to build and test simple electronic circuits. Investigate will provide you with a challenge which will allow you to further extend your learning, and finally, Amaze will show you the 'wow factor'!

IN THIS instalment of *Teach-In 2011*, we introduce some combined applications of analogue and digital circuits in the form of digital-to-analogue and analogue-to-digital converters (DAC, ADC). In ***Learn*** we explore the circuits and techniques used in DAC and ADC. ***Investigate*** extends this further with a look at a popular DAC, which is available from several semiconductor manufacturers.

Build looks at some further applications of digital circuits using both combinational and sequential logic techniques. Finally, in ***Amaze*** we look at the way that very large numbers are handled in digital systems.

Learn

Quantisation

Because signals in the real world exist in both digital (*on/off*) and analogue (*continuously variable*) forms, digital and computer systems need to be able to accept and generate both types of signal as inputs and outputs respectively. Because of this, there is a need for devices that can convert signals in analogue form to their equivalent in digital form, and vice versa.

This chapter introduces digital-to-analogue and analogue-to-digital conversion. We shall begin by looking at the essential characteristics of analogue and digital signals and the principle of *quantisation*.

In order to represent an analogue signal using digital codes, it is necessary to approximate (or quantise) the signal into a set of discrete voltage levels, as shown in Fig.9.1 The sixteen quantisation levels for a simple analogue-to-digital converter using a four-bit binary code are shown in Fig.9.2. Note that, in order to accommodate analogue signals that have both positive and negative polarity we have used the two's complement representation to indicate negative voltage levels.

Thus, any voltage represented by a digital code in which the MSB (most significant bit) is logic 1 will be negative. Fig.9.3 shows how a typical analogue signal would be quantised

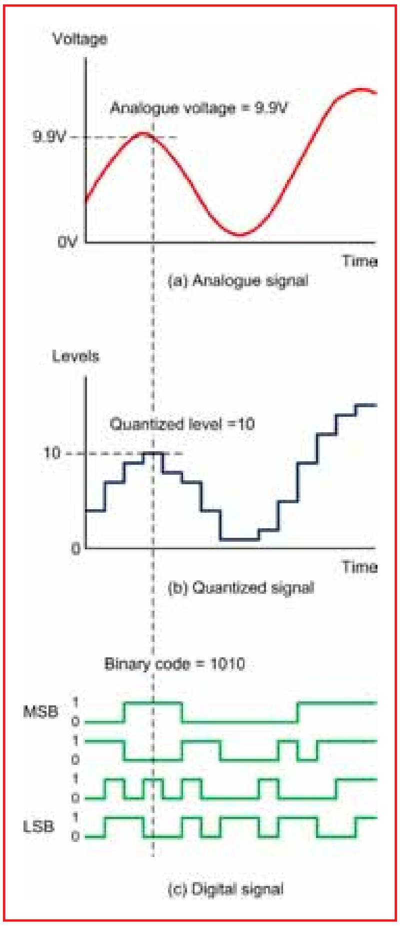


Fig.9.1. The process of quantising an analogue signal into its digital equivalent

into voltage levels by sampling at regular intervals (t_1, t_2, t_3, etc).

Digital-to-analogue conversion

The basic digital-to-analogue converter (DAC) has a number of digital inputs (often 8, 10, 12, or 16) and a single analogue output, as shown in Fig.9.4. The simplest form of DAC shown in Fig.9.5(a) uses a set of binary-weighted resistors to define the voltage gain of an operational summing amplifier and a four-bit binary latch to store the binary input while it is being converted.

Note that, since the amplifier is connected in inverting mode, the analogue output voltage will be negative rather than positive. However, a further inverting amplifier stage can be added at the output to change the polarity if required.

The voltage gain of the inputs to the operational amplifier (determined by the ratio of feedback to input resistance and taking into account the inverting configuration) is shown in Table 9.1. If we assume that the logic levels produced by the four-bit data latch are 'ideal' (such that logic 1 corresponds to +5V and logic 0 corresponds to 0V), we can

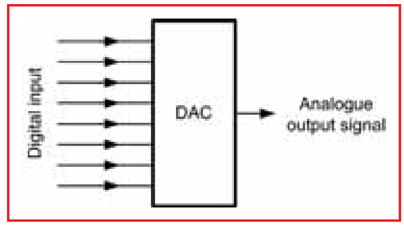


Fig.9.4. Basic DAC representation

determine the output voltage corresponding to the eight possible input states by summing the voltages that will result from each of the four inputs taken independently.

For example, when the output of the latch takes the binary value 1010 the output voltage can be calculated from:

$$V_{out} = (-1 \times 5) + (-0.5 \times 0) + (-0.25 \times 5) + (-0.125 \times 0) = -6.25V$$

Similarly, when the output of the latch takes the binary value 1111 (the maximum possible) the output voltage can be determined from:

$$V_{out} = (-1 \times 5) + (-0.5 \times 5) + (-0.25 \times 5) + (-0.125 \times 5) = -9.375V$$

Table 9.1. Table of voltage gains for the simple DAC shown in Fig.9.5(a)

Bit	*Voltage gain*
3 (MSB)	$-R/R = -1$
2	$-R/2R = -0.5$
1	$-R/4R = -0.25$
0 (LSB)	$-R/8R = -0.125$

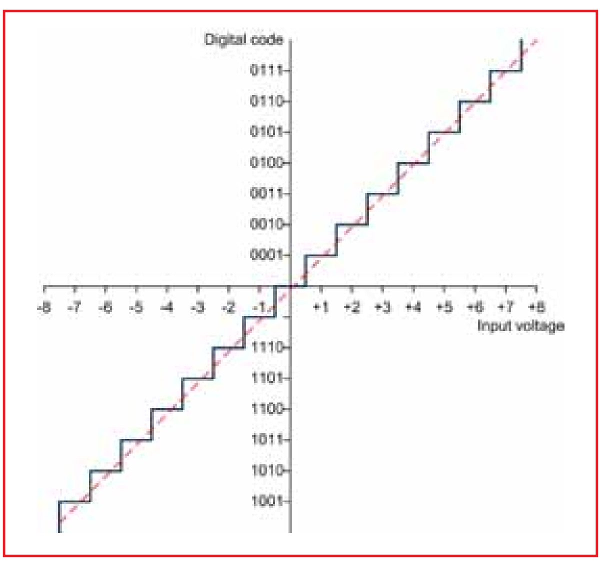


Fig.9.2. Quantisation levels for a simple ADC that uses a four-bit binary code

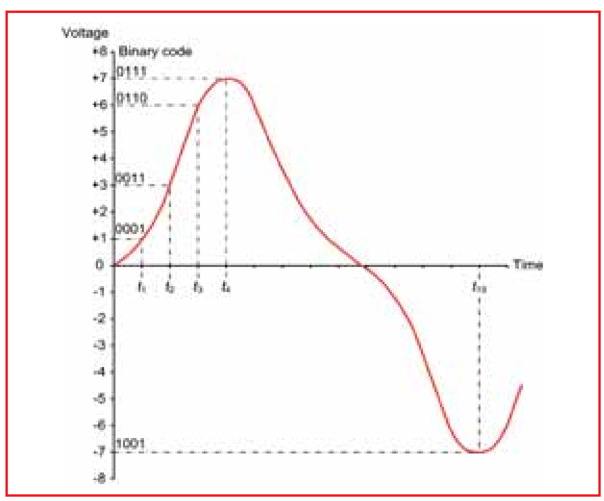


Fig.9.3. An analogue signal quantised into voltage levels by sampling at regular intervals (t_1, t_2, t_3, etc.)

The complete set of voltages corresponding to all eight possible binary codes is given in Table 9.2.

Binary-weighted DAC

An improved binary-weighted DAC is shown in Fig.9.5(b). This circuit operates on a similar principle to that shown in Fig.9.5(a), but uses four analogue switches instead of a four-bit data latch. The analogue switches are controlled by logic inputs so that a switch's output is connected to the reference voltage (V_{ref}) when its respective logic input is at logic 1, and to 0V when the corresponding logic input is at logic 0.

When compared with the previous arrangement, this circuit offers the advantage that the reference voltage is considerably more accurate and stable than using the logic level to define the analogue output voltage. A further advantage arises from the fact that the reference voltage can be made negative, in which case the analogue output voltage will become positive. Typical reference voltages are –5V, –10V, +5V and +10V.

Unfortunately, by virtue of the range of resistance values required, the binary-weighted DAC becomes increasingly impractical for higher resolution applications. Taking a 10-bit circuit as an example, and assuming that the basic value of *R* is 1kΩ, the binary weighted values would become:

Bit 0 1kΩ
Bit 2 2kΩ
Bit 3 4kΩ
Bit 4 8kΩ
Bit 5 16kΩ
Bit 6 32kΩ
Bit 7 64kΩ
Bit 8 128kΩ
Bit 9 256kΩ

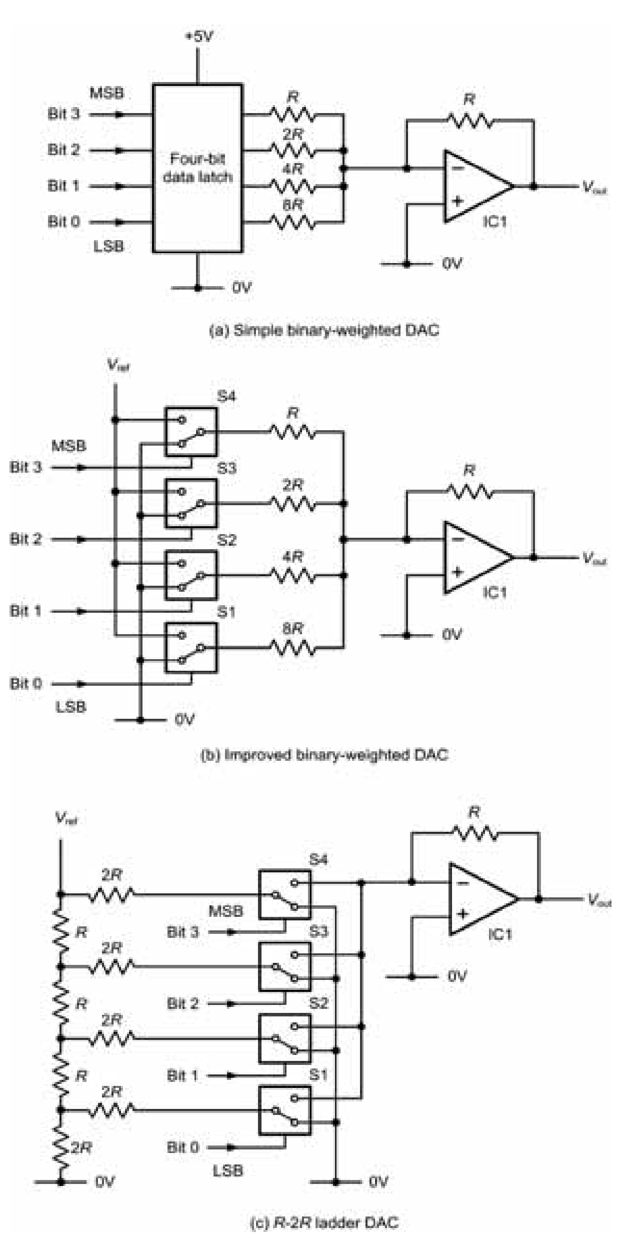


Fig.9.5. Simple DAC arrangements

Table 9.2. Output voltages produced by the simple DAC shown in Fig.9.5(a)

Bit 3	*Bit 2*	*Bit 1*	*Bit 0*	*Output voltage*
0	0	0	0	0V
0	0	0	1	–0.625V
0	0	1	0	–1.250V
0	0	1	1	–1.875V
0	1	0	0	–2.500V
0	1	0	1	–3.125V
0	1	1	0	–3.750V
0	1	1	1	–4.375V
1	0	0	0	–5.000V
1	0	0	1	–5.625V
1	0	1	0	–6.250V
1	0	1	1	–6.875V
1	1	0	0	–7.500V
1	1	0	1	–8.125V
1	1	1	0	–8.750V
1	1	1	1	–9.375V

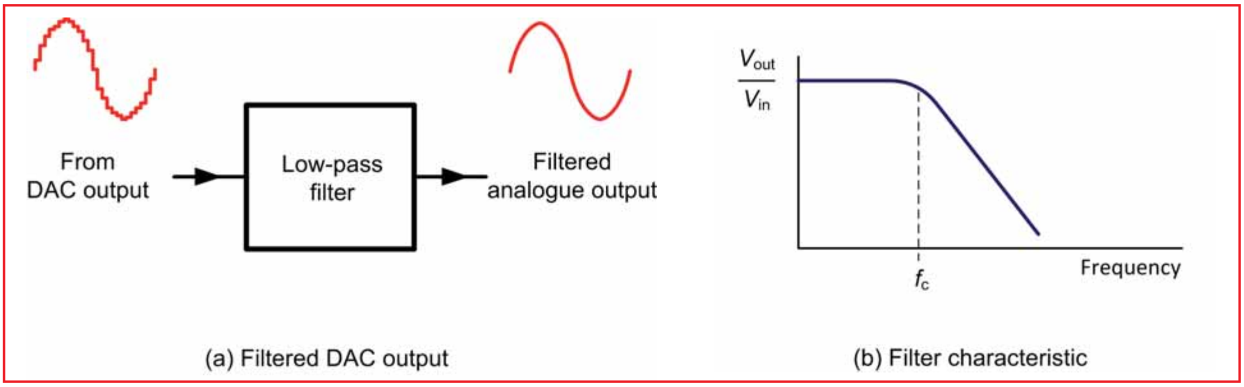


Fig.9.6. Filtering the output of a DAC

In order to ensure a sufficiently high degree of accuracy, all of these resistors would need to be close-tolerance types (typically ±1%, or better). A more practical arrangement uses an operational amplifier in which the input voltage to the operational amplifier is determined by means of an *R-2R* ladder, as shown in Fig.9.5(c).

Note that only two resistance values are required and that they can be any convenient value provided that one value is double the other (it is relatively easy to manufacture matched high-stability resistances of close tolerance on an integrated circuit chip).

Accuracy and resolution

The accuracy of a DAC depends not only on the values of the resistance used, but also on the reference voltage used to define the voltage levels. Special band-gap references (similar to precision Zener diodes) are normally used to provide reference voltages that are closely maintained over a wide range of temperature and supply voltages. Typical accuracies of between 1% and 2% can be achieved using most modern low-cost DAC devices.

The resolution of a DAC is an indication of the number of increments in output voltage that it can produce and it is directly related to the number of binary digits used in the conversion. The two simple four-bit DACs that we met earlier can each provide sixteen different output voltages, but in practice we would probably require many more (and correspondingly smaller) increments in output voltage.

This can be achieved by adding further binary inputs. For example, a DAC with eight inputs (ie, an 8-bit DAC) would be capable of producing 256 (ie, 2^8 or two raised to the power eight) different output voltage. A 10-bit device, on the other hand, will produce 1024 (ie, 2^{10} or two raised to the power ten) different voltage levels. The resolution of a DAC is generally stated in terms of the number of binary digits (ie, bits) used in the conversion.

Please note!

The *resolution* of a DAC depends on the number of bits used in the conversion process—the more bits the greater the resolution. Typical DACs have resolutions of 8, 10 or 12 bits.

Please note!

The *accuracy* of a DAC depends on the accuracy of the resistance values used, as well as the accuracy of the reference voltage. Typical DACs have accuracies of 1% or 2%

Filters

As we have seen, the output of a DAC consists of a series of quantised voltage levels. The presence of these levels on the output signal can be undesirable for some applications, and hence they are removed in order to 'smooth' the output voltage.

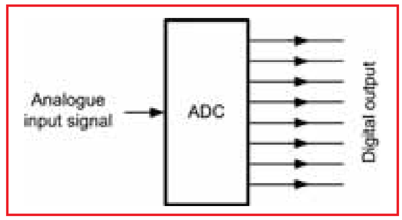


Fig.9.7. Basic ADC representation

This can be easily accomplished by passing the output signal through a low-pass filter, as shown in Fig.9.6. The filter is designed so that the residual sampling frequency components (ie, those that cause the 'steps' in the analogue signal) are well beyond the cut-off frequency of the filter and are subject to an appreciable amount of attenuation.

Analogue-to-digital conversion

The basic analogue-to-digital converter (ADC) has a single analogue input and a number of digital outputs (often 8, 10, 12, or 16 lines), as shown in Fig.9.7.

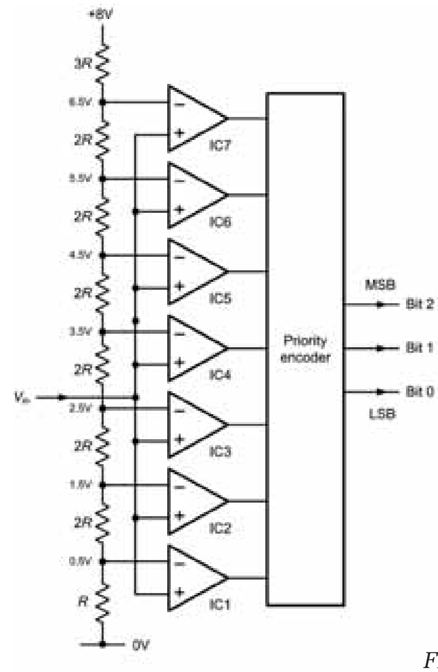
Various forms of analogue-to-digital converter are available for use in different applications, including multi-channel ADCs with up to 16 analogue inputs. The simplest form of ADC is the flash converter shown in Fig.9.8(a). In this type of ADC the incoming analogue voltage is compared with a series of fixed reference voltages using a number of operational amplifiers (IC1 to IC7 in Fig.9.8). When the analogue input voltage exceeds the reference

voltage present at the inverting input of a particular operational amplifier stage, the output of that stage will go to logic 1. So, assuming that the analogue input voltage is 2V, the outputs of IC1 and IC2 will go to logic 1 while the remaining outputs will be at logic 0.

The *priority encoder* is a logic device that produces a binary output code that indicates the value of the most significant logic 1 received on one of its inputs. In this case, the output of IC2 will be the most significant logic 1 and hence the binary output code generated will be 010 (as shown in Fig.9.8(b).

Flash ADC are extremely fast in operation (hence the name), but they become rather impractical as the resolution increases. For example, an 8-bit flash ADC would require 256 operational amplifier comparators while a 10-bit ADC would need a staggering 1024 comparator stages!

Typical conversion times for a flash ADC lie in the range 50ns to 1μs, so this type of ADC is ideal for 'fast' or rapidly changing analogue signals. Due to their complexity, flash ADC are relatively expensive.



(a) Simple flash ADC

Input	Output Bit 2	Output Bit 1	Output Bit 0
V_{in} < 0.5V	0	0	0
0.5V < V_{in} < 1.5V	0	0	1
1.5V < V_{in} < 2.5V	0	1	0
2.5V < V_{in} < 3.5V	0	1	1
3.5V < V_{in} < 4.5V	1	0	0
4.5V < V_{in} < 5.5V	1	0	1
5.5V < V_{in} < 6.5V	1	1	0
V_{in} > 6.5V	1	1	1

(b) Truth table

Fig.9.8. A simple flash ADC

Successive approximation

A successive approximation ADC is shown in Fig.9.9. This shows an 8-bit converter that uses a DAC (usually based on an *R-2R* ladder) together with a single operational amplifier comparator (IC1) and a successive approximation register (SAR).

The 8-bit output from the SAR is applied to the DAC and to an 8-bit output latch. A separate end of conversion (EOC) signal (not shown in Fig.9.9) is generated to indicate that the conversion process is complete and the data is ready for use.

When a start conversion (SC) signal is received, successive bits within the SAR are set and reset according to the output from the comparator. At the point at which the output from the comparator reaches zero, the analogue input voltage will be the same as the analogue output from the DAC and, at this point, the conversion is complete. The end of conversion signal is then generated and the 8-bit code from the SAR is read as a digital output code.

Successive approximation ADCs are significantly slower than flash

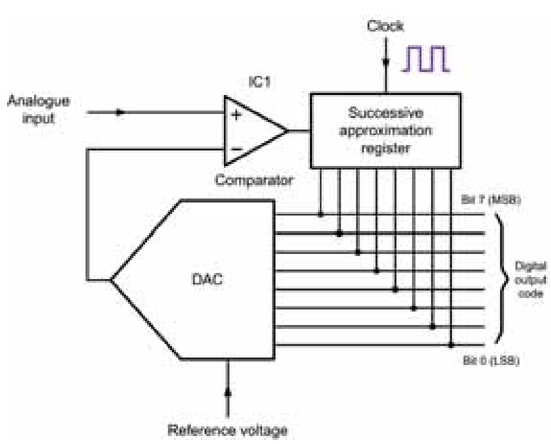


Fig.9.9. A successive approximation ADC

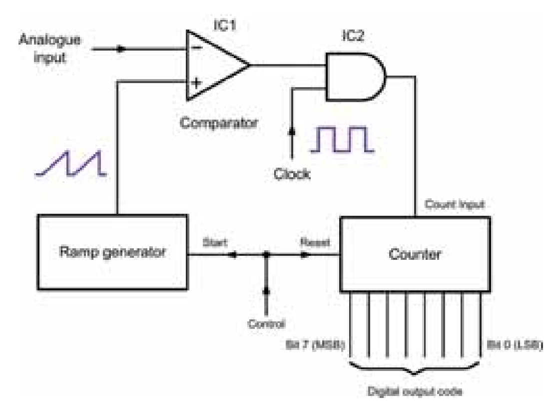


Fig.9.10. A ramp-type ADC

types and typical conversion times (ie, the time between the SC and EOC signals) are in the range 10μs to 100μs. Despite this, conversion times are fast enough for most non-critical applications, and this type of ADC is relatively simple and available at low-cost.

Ramping it up

A ramp-type ADC is shown in Fig.9.10. This type of ADC uses a ramp generator and a single operational amplifier comparator, IC1.

The output of the comparator is either a 1 or a 0 depending on whether the input voltage is greater or less than the instantaneous value of the ramp voltage. The output of the comparator is used to control a logic gate (IC2) which passes a clock signal (a square wave of accurate frequency) to the input of a pulse counter whenever the input voltage is greater than the output from the ramp generator.

The pulses are counted until the voltage from the ramp generator exceeds that of the input signal, at which point the output of the comparator goes low and no further pulses are passed into the counter. The number of clock pulses counted will depend on the input voltage and the final binary count thus gives a digital representation of the analogue input. Typical waveforms for the ramp-type waveform are shown in Fig.9.11.

Dual-slope ADC

Finally, the dual-slope ADC is a refinement of the ramp-type ADC, which

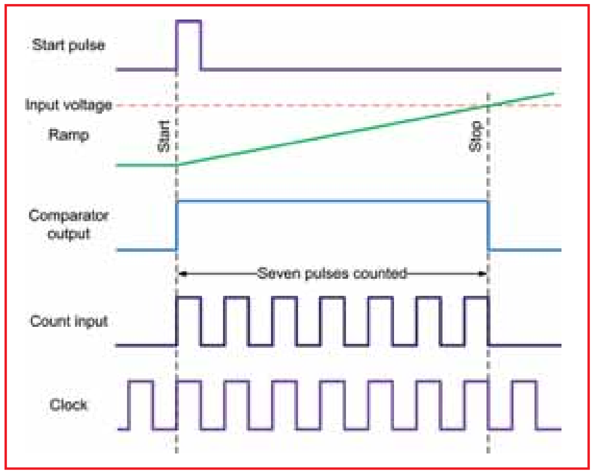


Fig.9.11. Waveforms for a single-ramp ADC

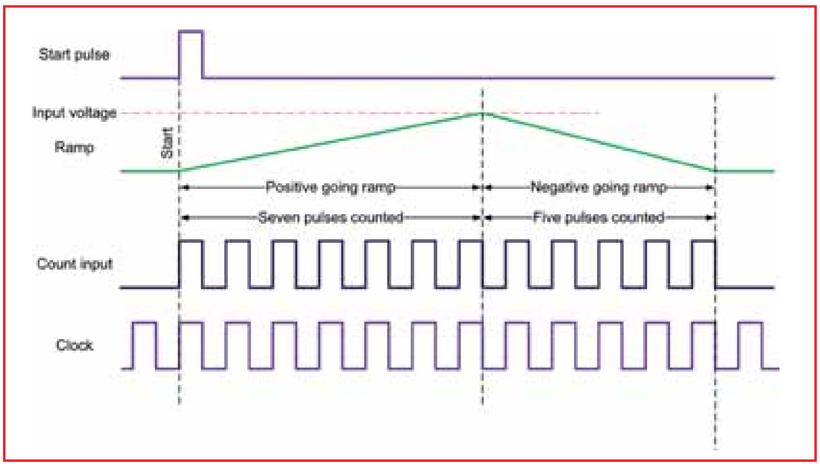


Fig.9.12. Waveforms for a dual-ramp ADC

Check – How do you think you are doing?

9.1. Explain with the aid of a sketch what is meant by quantisation.

9.2. A DAC can produce 256 different output voltages. What is the resolution of the DAC?

9.3. How many discrete voltage levels can be produced by a 10-bit DAC?

9.4. Explain the advantage of an *R-2R* ladder DAC compared a binary-weighted DAC.

9.5. State the advantage of a flash ADC and suggest an application in which it can be used.

9.6. The binary codes produced by a four-bit bipolar analogue-to-digital converter (see Fig.9.2 and Fig.9.3) sampled at intervals of 1ms, have the following values:

Time (ms)	*Binary code*
0	0101
1	0100
2	0011
3	0010
4	0001
5	0000
6	1111
7	1110

If the ADC uses two's complement to represent negative values (ie, 1111 represents -1, 1110 represents -2, and so on) sketch and identify the waveform of the analogue voltage.

For more information, links and other resources please check out our Teach-In website at:
www.tooley.co.uk/teach-in

involves a similar comparator arrangement, but uses an internal voltage reference and an accurate fixed slope negative ramp which starts when the positive going ramp reaches the analogue input voltage. The important thing to note about this type of ADC is that, while the slope of the positive ramp depends on the input voltage, the negative ramp falls at a fixed rate.

Hence, this type of ADC can provide a very high degree of accuracy and can also be made so that it rejects noise and random variations present on the input signal. The main disadvantage, however, is that the process of first ramping up and then ramping down requires some considerable time, and hence this type of ADC is only suitable for 'slow' signals (ie, those that are not rapidly changing). Typical conversion times lie in the range 500μs to 20ms.

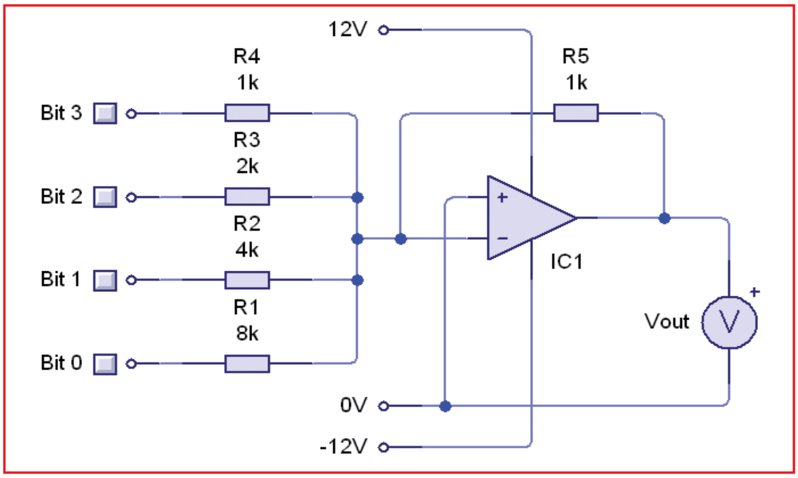


Fig.9.13. A simple four-bit binary-weighted DAC

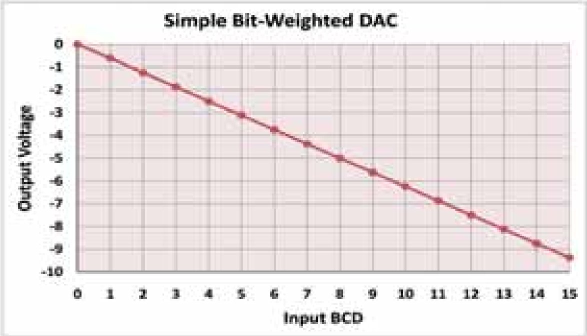


Fig.9.14. Graph of results for the simple four-bit binary-weighted DAC

IN this edition of ***Build*** we will try out some of the DAC circuits that we introduced in ***Learn*** (Fig.9.5). As we have seen, these can be constructed using operational amplifiers with cleverly arranged arrays of input resistors.

Binary-weighted DAC

First enter the simple binary-weighted DAC circuit shown in Fig.9.13. This is a practical circuit based on the one shown in ***Learn*** Fig.9.5(a). We have used a series of logic input toggles to simulate standard logic level inputs, with the output voltage shown on a virtual voltmeter instrument.

Set various input bit patterns and monitor the resulting output voltage. Using your theory from ***Learn*** to calculate the expected output voltage for two different input bit patterns and then test your answers using the simulation. Take readings of the output voltage for the binary coded decimal inputs from 0 (0000) to 15 (1111) and produce a graph of your results. Fig.9.14 shows our example results plotted using Microsoft Excel.

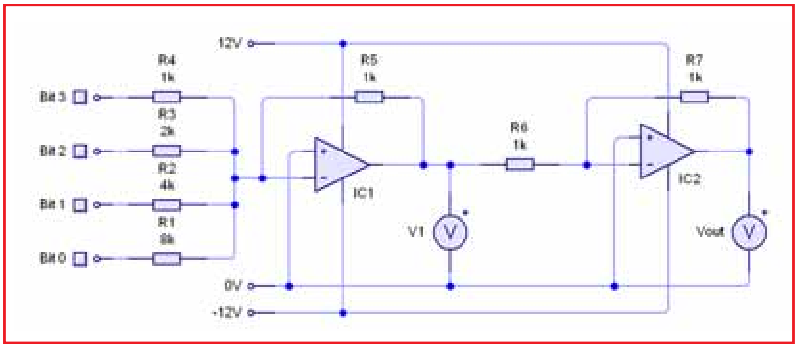


Fig.9.15. The modified four-bit binary-weighted DAC

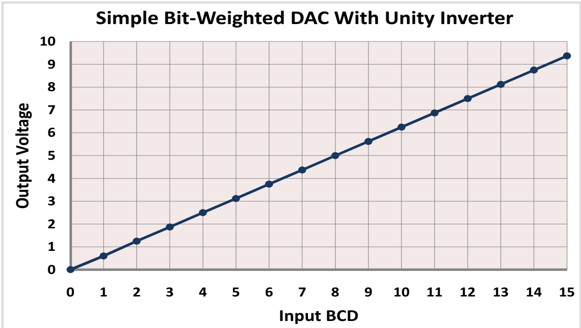


Fig.9.16. Graph of results for the modified four-bit binary-weighted DAC shown in Fig. 9.15

Build – The Circuit Wizard way

One of the drawbacks to the simple DAC circuit is the fact that by using an operational amplifier in an inverting configuration the output is negative. A common way of dealing with this issue is to add an additional inverting amplifier with a gain of -1. This is often referred to as a *unity gain* inverter.

Modify your binary-weighted DAC circuit (Fig.9.13) to that shown in Fig.9.15 below, and experiment with changing the input bits. Notice that the output of the first operational amplifier (V1) is equal in magnitude to the output voltage (V_{out}) but opposite in polarity. Plotting V_{out} against BCD input for this new arrangement should now look as shown in Fig.9.16.

A further modification to the binary-weighted DAC is shown in Fig.9.17. Here the output voltage is taken across the outputs of the two operational amplifiers. In this way the output voltage is effectively doubled. In fact, this method is commonly employed in many commercial DAC integrated circuit devices.

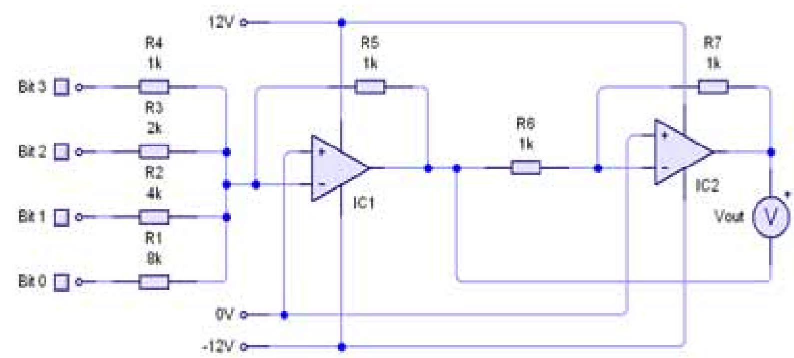


Fig.9.17. Improved binary weighted DAC with differential output

A switch in time

In Fig.9.5(b) we described an improved DAC circuit using analogue switches. We can model this quite simply for simulation purposes using single-pole double-throw (SPDT) switches, as shown in Fig.9.18. Note that in a real circuit these would be controlled by logic inputs.

Simulate the circuit by changing the binary input patterns by toggling switches SW1 to SW4. Notice that by having a negative reference voltage we achieve a positive output voltage. Experiment by changing the reference voltage (V_{ref}) and note how this affects the output voltage range.

On the ladder

Finally, we will try out a third type of DAC circuit that utilises a so called *R-2R* resistor ladder arrangement, like that shown earlier in Fig.9.5(c). As we discussed in ***Learn,*** there are practical advantages to this type of circuit; for example, only requiring one matched pair of resistor values. Construct the circuit shown in Fig.9.19 and experiment with the simulation.

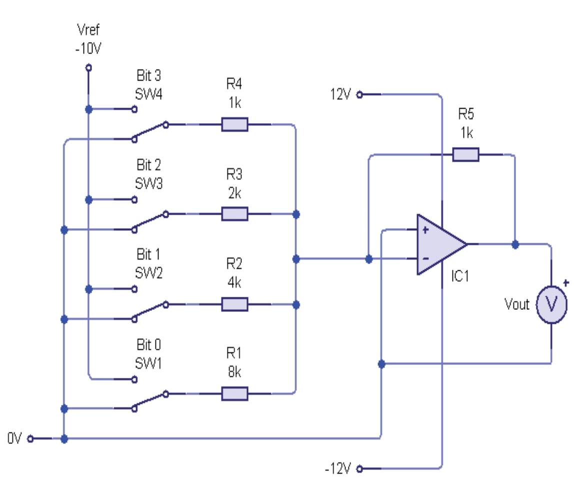


Fig.9.18. Binary-weighted DAC using analogue switches and a negative voltage reference

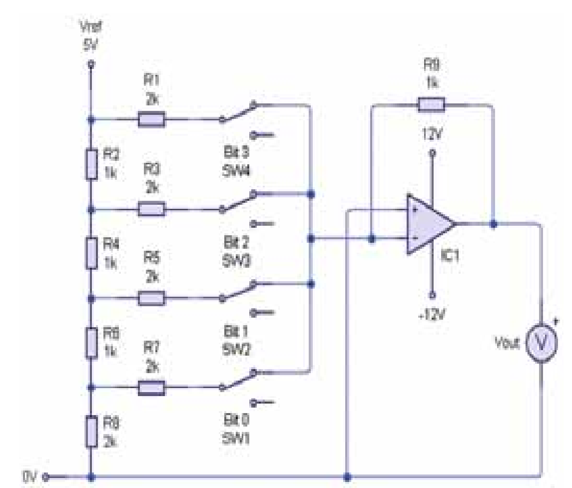


Fig.9.19. Four-bit DAC using an R-2R ladder arrangement

Investigate

ADCs and DACs invariably take the form of integrated circuit devices. Obtain data sheets for a DAC0800 digital-to-analogue converter (these can be freely downloaded from the websites of semiconductor manufacturers like National Semiconductor and Motorola) and use them to answer each of the following questions:

1. How many data bits are used?

2. What range of supply voltages can be used with this device?

3. What package styles are used for the device and how many connecting pins do the packages have?

4. What is the typical power consumption of the device when used with a ±10V supply?

5. What is the absolute maximum power dissipation for the device?

6. Which pins are used for (a) the LSB input and (b) the MSB input?

7. On what principle does the DAC operate?

8. What is the typical time taken for the output voltage to settle in response to a change at the input?

Amaze

As you have seen, the resolution of a DAC or ADC is determined by the number of data bits that it uses. The simple four-bit DAC that you met in ***Build*** was only capable of generating sixteen different voltage states. By increasing the number of bits we can gain a corresponding increase in the resolution. So, a five-bit DAC can produce 32 different output voltages, a six-bit DAC is able to produce 64 different output levels, and so on.

In many applications, the digital output of an ADC is processed using a computer or some form of embedded processor (such as those used in the engine control and management systems of motor vehicles). The unit of data in a computer (ie, the number of bits that can be handled by its processing unit as one single entity) is referred to as a *word*. So, ultimately, the digital output of an ADC must be converted into words that the computer or embedded system's processor can operate on. The number of bits in a word is an important characteristic of a particular processor family or computer architecture. This, in turn, has an impact on the size and range of the quantities that it can manipulate.

Early computers, such as the IBM PC and Commodore Amiga, as well as early console systems, such as the Sega Genesis, Super Nintendo, Mattel Intellivision, used a word length of 16-bits. This allowed them to manipulate integer numbers having a total of 65,536 different values.

More powerful 32-bit computers (such as the Apple Macintosh, Pentium-based PC and popular console systems, including the Sony PlayStation, Nintendo GameCube, Xbox, and Wii) have word lengths of 32-bits and this allows them to manipulate integer numbers that can represent 4,294,967,296 different values.

However, if that's not quite enough in terms of resolution, the most recent 64-bit systems including some games consoles, such as Nintendo 64, PlayStation 2, PlayStation 3, Xbox 360, can cope with integer numbers having a staggering 18,446,744,073,709,551,616 different values!

Answers to Check questions

9.1. See page 46 and Fig.9.1

9.2. 8-bit

9.3. 1024

9.4. Only two values are needed in the resistor chain of an *R-2R* ladder (the ratio of the two resistances is more important than their absolute values). The resistance values in a binary-weighted DAC can become very large when a large number of bits are used

9.5. High speed of operation. A typical application would be for use with high-quality audio and video signals (ie, analogue signals at relatively high frequencies)

9.6. Falling ramp (the analogue value falls linearly)

Next month!

In next month's Teach-In we will look at practical aspects of test instruments, measurements and testing circuits (including an introduction to PCB layout using *Circuit Wizard*).

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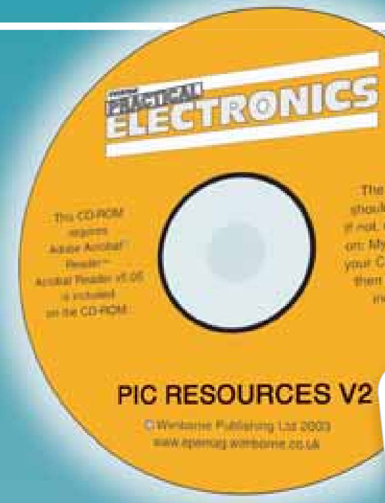

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LED current drivers

AS PART of a discussion on another contributor's LED drive circuit, frequent *EPE Chat Zone* contributor ***echase*** asked the following question about current source chips:

Where can I get a simple linear constant current driver that operates at 20mA and is low drop? I guess standard 78xx series of linear regulators can be made into a constant current driver, but the drop will be a few volts at minimum. I have used an LM334 in a similar application which is cheap, simple and only drops 0.5V, but it only manages about 8mA, so it needs three in parallel to get 20mA.

I want to power a string of four or five LEDs in series off a 12V supply with minimal loss. A standard dropper resistor is dodgy, as variations in the 12V and the LED change the volts dropped across the resistor, and hence makes the current vary a lot.

Later he answered his own question, with the following suggestions.

In a post last month, I asked if there was a simple constant current driver for LEDs that behaved like a LM334, but at higher current. Well, it seems the ON Semiconductor NSI45020A is available for only 40p from Farnell *and provides 20mA at up to 45V. There are 10mA, 15mA, 25mA and 30mA variants too. It's a 2-pin SOD123 SMD. Heat dissipation could be a problem if the* V_{in} *is more than10V larger than the LED voltage. At 2V it does not manage quite as low a 'drop out' voltage as the LM334.*

Also, RS do the 10mA and 15mA versions for less. They can be paralleled, so a mix of 10mA and 15mA devices provides a range of possible outputs.

Current drivers

Other chips were also suggested by Chat Zone contributors, specifically the LM317LZ and BCR402. So this month we will look at the need for constant current drive of LEDs, and the use of constant current regulator chips for this purpose. We will use the NSI45020A as an example device (where stated), although much of the discussion will apply to a range of similar chips from a variety of manufacturers, since echase mentions the NSI45020A is made by ON semiconductor (**www.onsemi.com**).

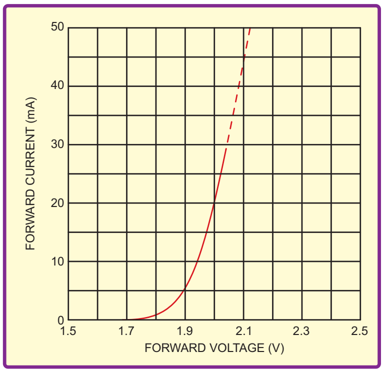

*Fig.1. Relationship of forward voltage and current for an example LED (*Kingbright L1334IT datasheet*)*

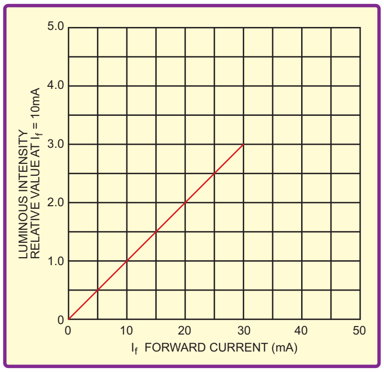

*Fig.2. Relationship of forward current and luminous intensity for an example LED (*Kingbright L1334IT datasheet*)*

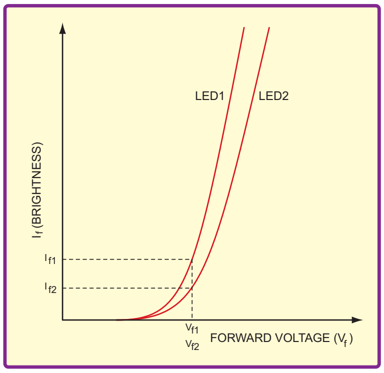

Fig.3. With the same forward voltage the LEDs may have different forward current and hence different brightness

The reason echase is asking about 'current drivers' is because LEDs are current controlled devices – in that the light output (brightness) is just about directly proportional to the forward current (a linear relashionship). So it is the current, not the voltage which sets the brightness. The characteristics of a typical high efficiency red 3mm LED (specifically the Kingbright L1334IT) are shown in Fig.1 and Fig.2.

Relationships

The relationship between forward current and voltage for the L1334IT, which follows the typical exponential diode curve, is shown in Fig.1. Fig.2 shows the very linear relationship between forward current and luminous intensity. By implication from Fig.1, the brightness does not vary linearly with forward voltage. The LEDs characteristics shown here may be similar to those used by echase (20mA at 2V drop), although he does not give very specific details in the quoted posts.

Two individual LEDs of the same type will produce the same illumination with the same forward current (I_f), but may have different forward voltage drops (V_f) at this current. Possible characteristics of two individual LEDs of the same type are shown in Fig.3.

With the same forward voltage, the LEDs may have different forward current, and hence different brightness. This is a key fact that needs to be considered when designing LED drive circuits, given that it is very common when using multiple LEDs to want to have all the LEDs at the same brightness.

Two LEDs driven in parallel is shown in Fig.4. This circuit forces the LEDs to have the same forward voltage drop, which means that their forward currents and hence brightness may be different (as in Fig.3). Fig.5 shows two LEDs with separate current-limiting resistors; we can still get problems with variation between individual devices resulting in varying brightness. An example will help explain this.

Assume for the circuit in Fig.5 we have two LEDs, with LED1 having a forward voltage drop of 2V, at a forward current of 20mA. If the supply (V_S) is 3.3V, we have R1 = 65Ω so that R1 drops 1.3V and we have 2V across LED1. If LED2 is also connected with

R2 = 65Ω, but has, say, a forward voltage drop of 2.2V, due to variations in individual device characteristics, the current in LED2 will be 16.9mA . The difference in current (15.5%) will be likely to show up as a noticeable difference in brightness.

If we use a higher supply voltage the brightness variation problem is reduced. For example, consider a 24V supply. Let's say we have R1 = 1.1kΩ to get 20mA with a 2V drop across LED1, so the LED is driven as before. Now consider LED2 with a 2.2V drop again and R2 1.1kΩ. The current in LED2 is

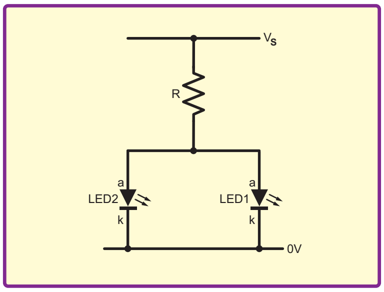

Fig.4. Driving two LEDs in parallel

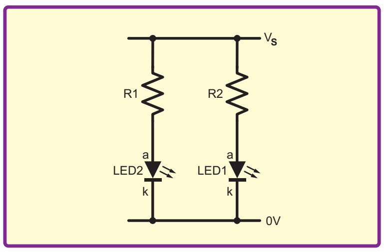

Fig.5. Two LEDs with separate current-limiting resistors

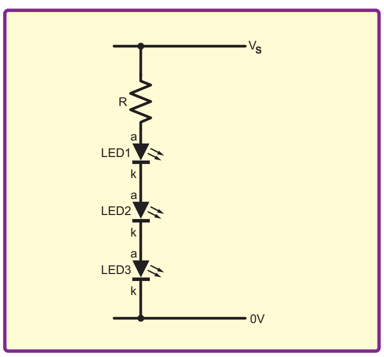

Fig.6. Driving LEDs in series ensures the same forward current, but requires a higher drive voltage

19.8mA, almost the same as LED1, so they will be closer to being equally bright (1% difference). This comes at a price though – the total power dissipation in the two current limiting resistors is about 0.87W in the second example, which is almost twenty times higher than in the first example. The second circuit is very inefficient.

Three LEDs driven in series is shown in Fig.6. The current through the LEDs must be equal, so their brightness will be equal. This approach requires a higher supply voltage – in this case something above 6V is needed for three LEDs at 2V each. For a small number of LEDs (as echase requires) the supply voltage requirement may not be a serious issue.

Potential problems

Despite the fact that the circuit in Fig.6 guarantees equal brightness there are still a few potential problems. First, we still have individual variability of the LEDs, so if we build two copies of the circuit then the brightness might not be the same.

This may not matter too much if this is for separate projects, but if we need to drive more LEDs than we can have in series across our supply voltage (so we use several LED strings) we are back to a similar problem described in Fig.5. As with the single LED, if the voltage across the resistor is relatively small, which it will be if we are trying to maximise the number of LEDs, then the variability will be more obvious.

Another problem with the circuit in Fig.6 is that the LED current, and hence brightness, will depend on supply voltage. This may not be a problem if the supply is well regulated, but if the supply is taken directly from a battery, for example, this could be an issue. Furthermore, if the supply is subject to high voltage spikes, as might be the case in an automotive application, then the resistor will not protect the LEDs from excessive current.

Finally, the LEDs in the circuit in Fig.6 may be subject to thermal runaway if conditions cause them to warm up sufficiently. LEDs have a negative temperature coefficient of forward voltage. This means that their voltage drop decreases as temperature increases.

In the circuit in Fig.6 this would cause the voltage across the resistor to increase, increasing the LED current. The increased LED current will lead to higher power dissipation, which may further increase their temperature. This temperature increase further increases the current and so on. It is possible for this situation to result in damagingly high currents in the LEDs.

Current driven

The problem with all the circuits described so far is that they are fundamentally *voltage* driven, but what we actually want to do is drive a specific *current* through the LEDs. Thus we need a current source, rather than the voltage source that we get with a standard power supply or battery.

An electrical source 'supplies' both current and voltage if it is doing anything useful, so when we say 'current' source we typically mean a *constant* current source. An ideal current source would power an LED – see Fig.7.

However, practical current sources are typically circuits designed to deliver a fixed current, rather than something like a battery or the mains, which act as actual sources of electrical energy. They obtain their power from a conventional voltage-based power supply (see Fig.8), thus strictly speaking they are 'constant current regulators' rather than true current sources, but behave (more or less) like current sources within the circuit context for which they are designed.

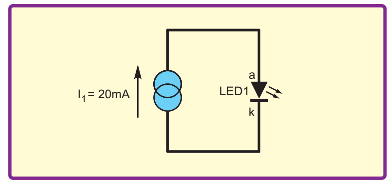

Fig.7. An ideal current source could power an LED directly, but practical current sources are usually just current regulators

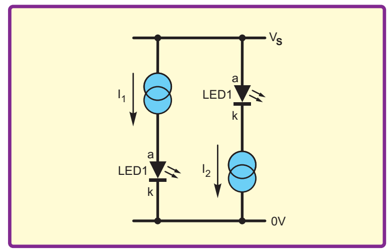

Fig.8. Here, I_1 is a current source or high side current regulator, while I_2 is a current sink or low side regulator

Current sources connected to ground, through which current flows to ground, are sometimes called current sinks (see Fig.8). The terms 'high side' and 'low side' are also used to describe current regulators which can be operated connected to the supply and ground respectively (see Fig.8).

An ideal current source outputs a particular current irrespective of the voltage(s) required at its terminals to achieve this. This corresponds with an ideal voltage source, which can deliver any current depending on the nature of the load.

In practice, of course, voltage sources are limited in terms of current capacity – an AAA 1.5V battery will not deliver 150A into a 0.01Ω load. Similarly, a small current source chip delivering 20mA will not handle the 1000V required to push this current through a 50kΩ load!

Operating voltage

The datasheets for current regulator chips, such as those mentioned by echase and others will specify the maximum voltage which can occur across the device. There will also be a minimum voltage which must be maintained across the chip in order for it to be able to operate, which is sometimes called 'voltage overhead' or 'dropout voltage'. This is because the internal components, such as transistors, will require this in order

to switch on and operate. Remember, for example, a bipolar transistor typically requires 0.6V to 0.7V base-emitter voltage to conduct.

To illustrate the operating voltage range for a real device, Fig.9 shows the characteristics of the NSI45020A two-terminal current regulator. The graph shows voltage across the NSI45020A against current through it. A minimum of around 2V is needed across the device for it to operate.

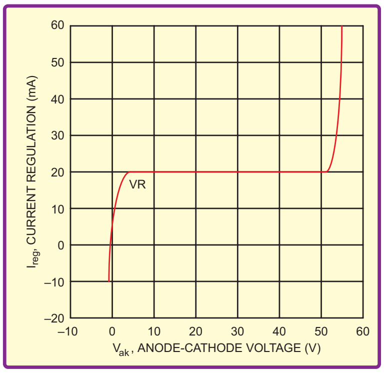

*Fig.9. Graph of voltage across the NSI45020A two terminal current regulator against current through it. Current regulation occurs between 2V and 50V approximately (*ON Semiconductor datasheet*).*

Current is constant for voltages above this, until the device breaks down at around 50V (the specified maximum voltage is 45V). This means than unlike resistor-based circuits, such as Fig.6, use of a current regulator will result in constant LED brightness for a reasonable range of supply voltage variation.

The ability of devices such as the NSI45020A to regulate up to quite high voltages (eg, 50V) can protect LEDs from supply voltage spikes. Consider the circuit in Fig.5 with a 12V supply, three 2V, 20mA LEDs and a 300Ω resistor. A 50V pulse on the supply would dramatically increase the LED current. If we assume each LED voltage drop increases to 2.4V (an arbitrary guesstimate, but the exponential diode characteristic means the LED voltage will not change much) the LED current will be around 140mA from (50–(2.4×3))/300.

Using the Kingbright L1334IT mentioned earlier as an example, we find the absolute maximum continuous current is 30mA, and the absolute maximum forward pulse current is 160mA for a 0.1ms pulse width. A 50V pulse causing 140mA for significantly longer than this may damage the LEDs. Using a current regulator that can regulate up to 45V would maintain the 20mA LED current during the 50V spike. The current regulator will experience increased power dissipation during the surge, but with correct thermal design (board layout/heatsinking) it should not be damaged.

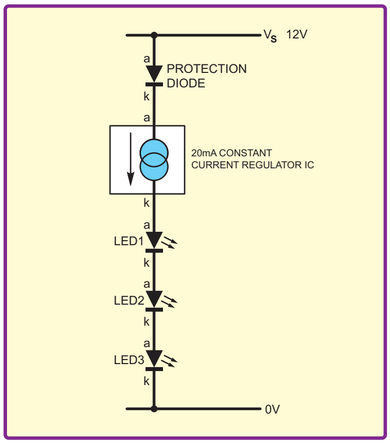

Fig.10. Example LED drive circuit using a current regulator IC

Looking at the graph in Fig.9, we see that current in the NSI45020A increases very rapidly with increasing reverse voltage across the device. It follows that the NSI45020A is likely to be damaged by reverse connections, and therefore in systems where supply reversal may occur (eg, incorrectly connected batteries) a reverse protection diode should be used.

A perfect current source would prevent LEDs from being subject to thermal runaway because the current would not vary with temperature. Real current regulators are likely to have some temperature dependency. Fortunately, it is possible to ensure a small negative coefficient, which prevents thermal runaway (the NSI45020A and similar devices provide this). The regulator temperature coefficient should not be large because this may result in brightness variation with temperature.

As mentioned above, current regulators have an overhead voltage, above which they will operate correctly. This may be specified at something below the full regulated current (say 85%). Therefore, in practice, it is best to use the device at a voltage a bit above this, so that the device is into the full regulation part of the characteristic (the flat line section on Fig.9). For the NSI45020A, about 3.5V would be reasonable.

Ideally, the voltage across the regulator will not be much larger than this minimum because power dissipation increases, and efficiency decreases, for larger voltage drops. However, voltage dropped depends on the supply voltage and number of LEDs used, so some regulator dissipation will be unavoidable. If efficiency is particularly important, then switch-mode LED driver chips can be used, but these circuits are more complex and expensive.

The number of LEDs which can be driven can be calculated by subtracting the overhead voltage and reversal protection diode forward voltage (if used) from the supply

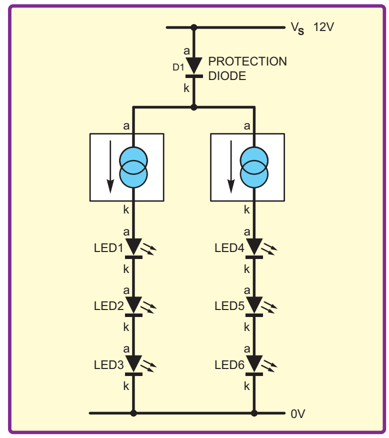

Fig.11. Driving more LEDs

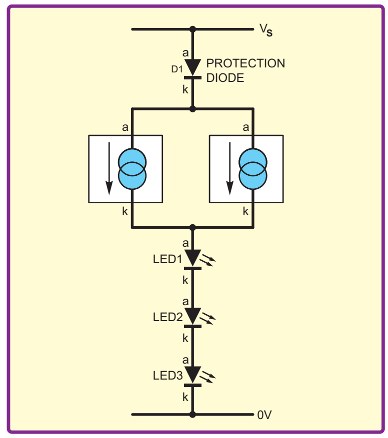

Fig.12. Driving at higher current

voltage, and then dividing this value by the expected LED voltage drop at the regulated current. For example, for a 12V supply, we assume a regulator drop of 3.5V, protection diode drop of 0.7V and an LED forward drop of 2V at 20mA; the maximum number of LEDs is (12 – 3.5 – 0.7)/2, which gives 3.9 LEDs.

Allowing a slightly lower regulator voltage would make driving 4 LEDs possible, but some LED dimming may occur if the supply voltage dropped, due to operating close to the 'knee' in the regulator characteristic. Using three LEDs would allow more supply variation without the LEDs dimming. With three LEDs, the regulator would drop 5.3V and dissipate around 110mW. This is within the capabilities of the NSI45020A and similar devices. A suitable circuit is shown in Fig.10.

To drive more LEDs, several regulator ICs can be used to drive parallel LED strings, as shown in Fig.11 (typically only one reverse protection diode would be needed). To increase current drive, current regulator ICs can usually be operated in parallel (see Fig.12). Unlike parallel LEDs (Fig.4), which may current hog; they keep to their specified regulation current (within the operating voltage range).

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Practically Speaking

Robert Penfold looks at the Techniques of Actually Doing it!

A multi-range test meter, or 'multimeter' as these devices are generally called, used to be a major investment. A professional grade instrument cost a sum that was equivalent to several weeks' wages for 'mister average'. The better low-cost types were less rugged and probably a little less accurate as well, but were good enough for amateur and even some professional use.

However, by the standards of the day they still represented a significant outlay. A multimeter was something that you bought after gaining some experience at electronics construction, if you could afford one.

Some types of test equipment are still relatively expensive today, but non-professional multimeters have gone the way of many electronic gadgets, and can now be obtained at quite low prices. On a certain well-known auction site it is possible to buy them direct from the Far East for around three pounds including postage.

If you are not prepared to wait a few weeks for delivery, they can be obtained in the UK for not a great deal more. At these prices, it is probably better to invest in a multimeter sooner rather than later.

Speed reading

There are two main types of multimeter; the analogue and digital varieties (Fig.1). The analogue type has the readout provided by a conventional moving meter that has a fine pointer 'needle' and a scale. The digital type has a digital readout that on the lower cost units is typically a three or three and a half digit type.

While it might seem surprising that analogue multimeters are still available in this day and age, they do have a few advantages. Where a high degree of accuracy is not needed it is possible to read an analogue multimeter at a glance. You can see immediately whether the reading is 'in the right ballpark', and that is often all you need to know.

An analogue instrument is also easier to use when adjusting a preset resistor to obtain a certain voltage at a test point, or something of this general nature. As you adjust the control, the meter's pointer responds immediately and smoothly to the changes.

Using a digital multimeter for this type of thing you tend to get a confusing set of readings. It then becomes a matter of adjusting the control, waiting for the reading to settle, adjusting the control again, waiting again, and so on until eventually the required reading is obtained.

In a similar vein, if a voltage is fluctuating slowly, an analogue instrument will follow and show the changes. In the same situation, a digital type tends to become a random number generator!

Another advantage of analogue multimeters is that they can still measure voltage and current if the battery goes flat. The battery is only needed for resistance (ohms) measurement, and probably for additional features such as a continuity buzzer and semiconductor testing.

A disadvantage of analogue multimeters is that they often require two batteries. Typically, there will be one or two 1.5V batteries plus a higher voltage type, such as a PP3 9V battery. In most cases, the higher voltage battery is only required for the highest resistance ranges.

On reflection

Although the analogue type has its advantages and is still preferred by some, a digital instrument is generally the better choice. Even a three-digit type is likely to offer better accuracy than that provided by the pointer and scale of an analogue multimeter. Small analogue types are handy devices, but the longer scale of a larger type can be read more accurately.

Most analogue multimeters have an arc with a mirror finish mixed in with the various scales. This aids reading accuracy by combating parallax problems due to the pointer being slightly raised from the scale plate. Accurate readings are obtained when the pointer covers its reflection in the mirrored part of the scale, but for highly accurate readings a digital type is still likely to be quicker, easier, and more precise.

Many multimeters have a three and a half digit display, which is a type where the maximum reading is 1999. The extra 'half' digit gives better results on awkward readings such as 1.295V. This is no problem with a three and a half digit display, where it fits in nicely on the 1.999V range.

Fig.1. The analogue meter on the left cost about the same as the digital type on the right, and they offer similar facilities. The digital type is smaller, more rugged, and probably offers slightly better accuracy

With a three-digit type, it would have to be read on the 10V range, and would be displayed as 1.29V. The loss of a digit from the reading is unlikely to be of major importance, but most multimeters, whether digital or analogue, provide significantly reduced accuracy at low readings. I would always opt for a three and a half digit type, but in practice it is likely that both types will do a perfectly good job.

Input resistance

Digital multimeters tend to have the advantage of being more rugged. The moving coil meter movement of an analogue multimeter is very delicate, and dropping any instrument that contains a moving coil meter is definitely not a good idea!

The meter movements in analogue multimeters are relatively large, but have been designed to respond to minute amounts of current. This makes them especially vulnerable. A severe jolt can impair the accuracy of the meter, and in a severe case the pointer can be dislodged from its bearings.

The vast majority of analogue multimeters are passive devices when measuring voltage. In other words, there is no amplifier between the test point and the meter movement. There is just a resistor in series with the meter, and the value of this resistor determines the full-scale voltage. The power needed to drive the meter movement is obtained from the test point.

This is a far from ideal approach, since the power tapped off by the meter can significantly load the voltage at the test point, giving a misleadingly low reading. The meter needs to be as sensitive as possible in order to minimise loading effects, but there is a limit to the sensitivity that can be obtained while maintaining a reasonable level of ruggedness.

The sensitivity of analogue meters is expressed in terms of so many kilohms-per-volt (k/V), and the cheaper types usually have a rating of one or two kilohms per volt. If (say) a 1k/V meter is set to the 10V range, it will have a resistance of 10kΩ, and it will draw one milliamp from the test circuit with a full-scale reading. This is of no consequence for something like checking the output voltage of a battery or a battery eliminator, but with modern low-current circuits it is likely to give frequent misleading readings when making voltage checks at various parts of a circuit.

The more expensive analogue multimeters usually have a sensitivity of 20k/V, which gives a resistance of 200kΩ on the 10V range, and requires just 50μA for a full scale reading. This is good enough to ensure that loading effects will only occasionally have to be taken into account when testing circuits.

Small analogue units that have low sensitivities are fine for things like checking batteries, and testing switches using a resistance range, but a larger and more expensive type is better suited to making voltage checks on circuits. In terms of input resistance, digital multimeters are even better though. Most have a constant input resistance of about 10 or 20MΩ, which is high enough to ensure that it will hardly ever be necessary to take loading effects into account.

Resistance ranges

In general, the cheaper multimeters have fewer measuring ranges than the more upmarket types, and this tends to be especially noticeable with the resistance ranges. Most multimeters can measure quite low resistances without any problems, and it is the higher ranges above a megohm that tend to be absent on the budget models. High value resistors are not used a great deal in modern electronics, but they are used to a significant extent in multimeters, and it is probably worth paying a bit extra for a meter that covers resistances up to at least 10 or 20MΩ.

Resistance measurement using a digital multimeter is very straightforward, but there are a few complications with the resistance range of analogue types. With a suitable range selected, the two test prods are connected together and a control on the multimeter is adjusted to zero the reading.

However, zero for resistance measurements is at what is normally the full scale reading, and the resistance scales read in reverse. Furthermore, they are non-linear, with the scales getting increasingly cramped towards the high end of each range. This is not to say that an analogue multimeter cannot provide accurate resistance readings, but you do need to keep your wits about you in order to avoid reading errors, and it is all a bit primitive in comparison to a resistance measurement using a digital type.

It is not just extra resistance ranges that are provided by the more upmarket meters, and there will usually be extra ranges for some other types of measurement, and extra facilities. Even the cheaper multimeters often sport facilities such as diode and transistor testing, and possibly a continuity tester feature.

It is possible to test for continuity using a low resistance range, but a facility specifically for that task will normally indicate continuity by sounding a buzzer. This is more convenient in use as it avoids the need to look away from the test prods.

The more expensive multimeters (Fig.2) will usually have the ability to measure things that are not available at all with the cheaper types. Ranges for

Fig.2. This mid-price digital meter has more ranges and facilities than a budget unit, including six capacitance ranges. It also has a large and easily read display

measuring AC current are often absent from budget multimeters, but should be included with the more expensive meters. Measuring AC current is something you might never need to do, so the absence of this facility is probably not of great importance.

The capacitance ranges provided by the more expensive digital multimeters are a different matter, and the ability to check capacitors with values from a few picofarads to several hundred microfarads is a huge bonus.

Fluke-alikes

Moving still further up the price range, there are units that look similar to the Fluke range of professional meters, and in most cases they offer a similar range of facilities. The additional features on offer usually include frequency and temperature measurement. Temperature measurement is accomplished using a separate probe, and it is used to check that power devices are not in danger of overheating. Additional features such as these are potentially useful, but the laws of diminishing returns tend to apply here. It can cost quite a lot extra for features that you might never use in earnest.

The more upmarket meters usually have auto-ranging. In other words, you just select the desired function such as DC voltage, connect the meter to the test points, and the meter does the rest. It will select the best range, put the decimal point in the right place, and indicate the units in use.

Apart from convenience, this has the advantage of avoiding the risk of overloads. There is no danger of (say) selecting a low voltage range and connecting the meter to a hundred volts or so, because the user does not select the range.

However, it is still essential to select the right function. Selecting the resistance function and connecting the meter to a few hundred volts might not have a happy outcome! All multimeters have some built-in protection against overloads and misuse, but as always with this type of thing, it is best if it is never given the 'acid test'.

Pen name

I am not entirely sure that the 'pen' name is entirely appropriate for this type of multimeter (Fig.3), which is indeed held like a pen, but in terms of weight and bulk tends to be very much bigger than any normal pen. More out of curiosity, than because I thought it would be a valuable piece of test gear; I bought one of these many years ago when they first came out. I actually used it more than my normal analogue and digital units, and eventually wore it out.

Pen style multimeters are very convenient for many types of testing because the display is very close to the test point, and the meter itself is effectively one of the test prods. This largely avoids the tendency for the test prod to slip from the test point while your attention is required to read the display.

They are probably not a good choice for a first multimeter though, as they are relatively expensive and have some drawbacks. Auto-ranging is a standard feature of these units, but the specification can be relatively modest in other respects. There will usually be AC and DC voltage ranges, resistance measurement, and perhaps a facility for testing diodes, but there will probably be little or nothing else.

In use

In order to get the most from a multimeter it is necessary to have a fair amount of technical knowledge. Even if a circuit diagram includes test voltages, without a reasonable understanding of electronics theory it is unlikely that any readings that are wide of the mark will enable the fault to be pinpointed.

On the other hand, it is possible to make some general tests that might help to locate the problem. A low resistance range or a continuity tester function can be used to check switches, test for broken tracks on a circuit board, and test for bad soldered connections. Using a DC voltage range it is possible to check that the battery is providing an adequate voltage, and that the voltage is getting through to the circuit board.

Fig.3. A pen style multimeter such as this offers a convenient way of making voltage checks. However, prices are relatively high and the range of features provided tends to be quite limited

It is also possible to check some components. Obviously, resistors can be checked using the resistance ranges, but bear in mind that components cannot be checked while they are fitted on the circuit board. When checking any component, at most, there must be no more than one lead connected to the board.

When testing high value resistors, it is important not to touch both of the metal prods or component leads. Doing so results in the resistance through your body being connected in parallel with the test component, which could significantly reduce readings.

Most multimeters can be used to check transistors and diodes, and it is probably worth paying a little extra to get one that can check capacitors as well.

One final point is that the test leads/prods supplied with low cost multimeters are usually of the 'cheap and cheerful' variety. This is not really surprising, since a pair of high quality prods costs more than most budget multimeters! Even so, if you use a multimeter a great deal it is probably worth investing in a higher quality type, such as the ones that have spring-loaded claws that can grip component leads, tags and solder pins.

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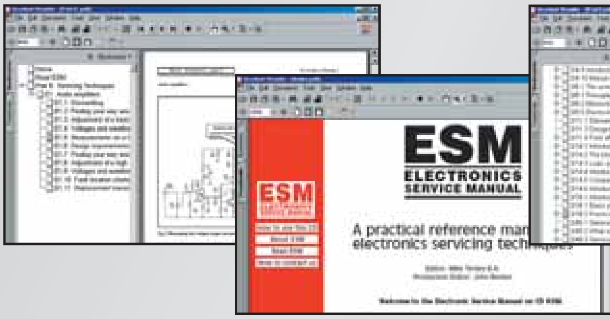

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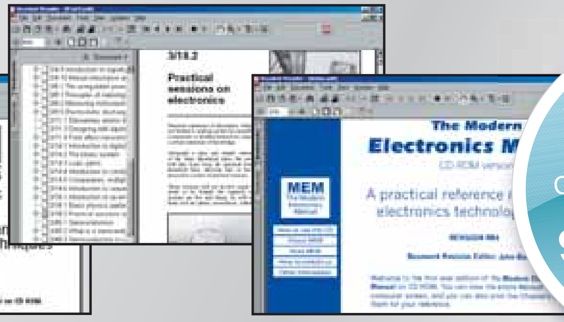

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Max's Cool Beans

By Max The Magnificent

My Boomerang won't come back

As you may recall, in my previous column I waffled on about a Geiger counter kit that I had purchased and constructed. The kit looks really cool, but sadly it doesn't count. When I turn it on, the blue LED lights up and stays on, but nothing else happens. I've since learned that the LED should only flash on to indicate a radiation event.

I've been asking around on the Internet and have been in touch with several other people who have the same kit. One person jokingly said that my remark 'my Geiger counter doesn't count' reminded him of the song 'my boomerang won't come back.' As fate would have it, this is a little ironic, because my counter is currently in Australia. Some say that their units behave just like mine – that is, they don't work at all – and these folks aren't very happy about it. Others say that their kits work just fine. One person pointed me to a video on YouTube (**www.youtube.com/watch?v=Q58-l1KYrTg**) that shows an identical unit working as you would expect. Whoever took the video has the Geiger counter sitting close to an orange Fiesta Ware plate that was naturally radioactive (this variety of Fiesta Ware was discontinued because of it). The counter clicks away at a fairly high rate, which falls when the plate is moved further away toward the end of the video.

I'm not all that familiar with the way in which these things perform their magic. Fortunately, I have a friend called David Ashton who lives 'down under' in Australia. David is an electronics expert who can fix almost anything. So, at his invitation I shipped my Geiger counter to him (the post cost only $5, which I thought was an amazingly good deal). A few days ago, David emailed me to say that the unit had arrived, so now I am all aquiver in anticipation.

One of the problems I ran into when I first constructed the Geiger counter was that I didn't know how it should behave, and how often it should trigger due to background radiation. I simply didn't have a radiation source to hand with which to test it.

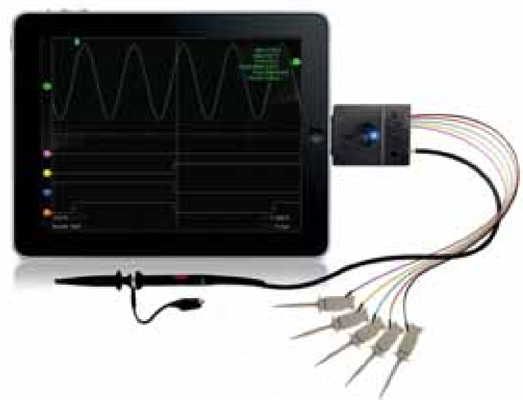
I mentioned all of this in my postings on the Internet. Shortly after I'd returned from dispatching my Geiger counter to Australia, I received an email from Nick Bricteux (**www.xtor.us**) saying that he had just posted two uranium glass marbles to me. Nick also assured me that these are perfectly safe, being only about five to ten times more active than background radiation.

The marbles arrived a few days ago and are sitting on my desk as we speak. Life can be a funny old thing, can't it? First I had a Geiger counter, but no source of radioactivity. Now I have a pair of radioactive marbles but no Geiger counter.

Mega cool iPad oscilloscope

One thing that would have been very useful with regard to debugging my Geiger counter would have been an oscilloscope. Sad to relate, I don't currently own one (my old one died and I never got around to replacing it).

By another strange quirk of fate, I now have a scope sitting on my desk. This is a really clever little device called the iMSO-104 from Oscium (**www.oscium.com**). Now I've seen FPGA-based oscilloscopes that plug into the USB port on a PC, but I've never seen anything similar for the iPad.



In this image, the iMSO-104 is the small connector/adapter plugged into the right-hand side of a standard iPad. The software is free to download from the Apple Store (it runs in demo mode without hardware attached). The really cool thing is that the iMSO-104 and its software are compatible with all hardware iterations of the iPad, iPhone, and iPod touch.

The iMSO-104 simultaneously supports four digital channels up to 5MHz and one analogue channel up to 12 mega-samples per second. On the one hand these aren't tremendously high performance values – on the other hand they would work well for many of my projects.

I really like the fact that it works with an iPhone and an iPod Touch (I'd like it even better if I had an iPod Touch myself). The thing is that a lot of folks already have one of these products, so the ability to turn it into an oscilloscope is rather cool.

One of the nice things about this is the intuitive usage model, which takes full advantage of the iPad-iPod-iPhone touch screens. Setting the analogue trigger level, for example, is as easy as touching the right side of the screen and swiping either up or down. Changing the vertical and horizontal scales can be achieved by moving two fingers away from each other. And you can rearrange things by touching and swiping the desired channel to any position on the screen to customise your display.

Of course, cost is also a factor. At $297.99 (£200 approx), the iMSO-104 isn't particularly cheap. On the other hand, it's in line with FPGA/USB equivalents for PCs. Of course, it's true that FPGA/USB equivalents for PCs can typically handle higher bandwidths and trigger rates; but then you also have to lug around a PC with you.

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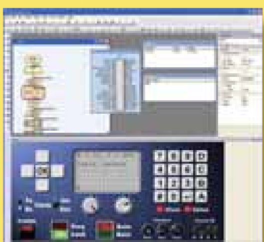
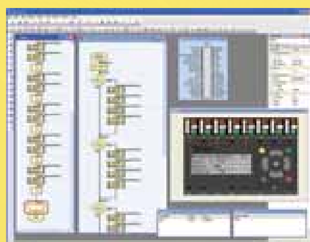
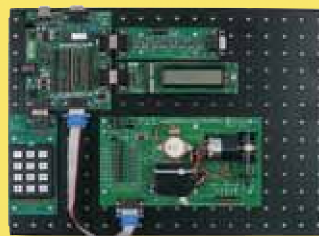


Design
Flowcode contains standard flow chart icons and electronic components that allow to you to create a virtual electronic system on screen. Drag icons and components onto the screen to create a program, then click on them to set properties and actions.



Simulate
Once your system is designed you can use Flowcode to simulate it in action. Design your system on screen, test the system's functionality by clicking on switches or altering sensor or input values, and see how your program reacts to the changes in the electronic system.



Download
When you are happy with your design click one button to send the program directly to your microcontroller based target. Targets include a wide range of microcontroller programmers, upstream E-blocks boards, the Formula Flowcode robot, the MIAC industrial controller, or your own system based on ECIO technology.

FlowKit
The FlowKit can be connected to hardware systems to provide a real time debug facility where it is possible to step through the Flowcode program on the PC and step through the program in the hardware at the same time. The FlowKit can be connected to your own hardware to provide In-Circuit Debug to your finished designs.

PRICES
Prices for each of the CD-ROMs above are: ***(Order form on third page)***

(UK and EU customers add VAT to 'plus VAT' prices)

Hobbyist/Student	**£45.95**	**inc VAT**
Professional (Schools/HE/FE/Industry)	**£149**	**plus VAT**
Professional and Flowkit bundle	**£175**	**plus VAT**

PICmicro TUTORIALS AND PROGRAMMING

HARDWARE

VERSION 3 PICmicro MCU development board

Suitable for use with the three software packages listed below.

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- Makes it easier to develop PICmicro projects
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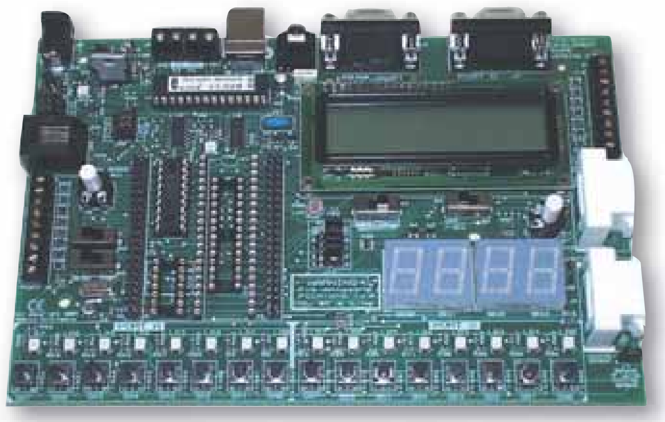


£161 including VAT and postage, supplied with USB cable and programming software

SOFTWARE

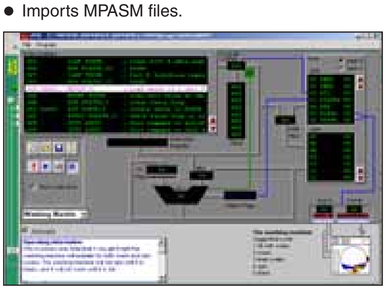
ASSEMBLY FOR PICmicro V3

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

● Comprehensive instruction through 45 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture and functions ● Expert system for code entry helps first time users ● Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) ● Imports MPASM files.

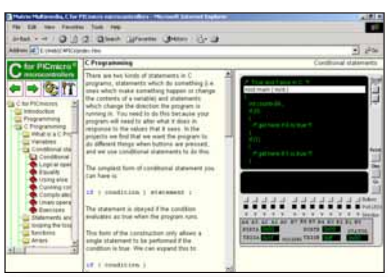


'C' FOR 16 Series PICmicro Version 4

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD-ROM contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

● Complete course in C as well as C programming for PICmicro microcontrollers ● Highly interactive course ● Virtual C PICmicro improves understanding ● Includes a C compiler for a wide range of PICmicro devices ● Includes full Integrated Development Environment ● Includes MPLAB software ● Compatible with most PICmicro programmers ● Includes a compiler for all the PICmicro devices.



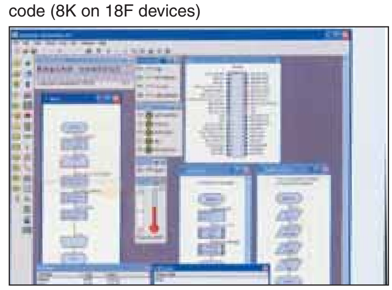
Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V4

Flowcode is a very high level language programming system based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

- Requires no programming experience
- Allows complex PICmicro applications to be designed quickly
- Uses international standard flow chart symbols
- Full on-screen simulation allows debugging and speeds up the development process.
- Facilitates learning via a full suite of demonstration tutorials
- Produces ASM code for a range of 18, 28 and 40-pin devices
- 16-bit arithmetic strings and string manipulation
- Pulse width modulation
- I2C.

New features of Version 4 include panel creator, in circuit debug, virtual networks, C code customisation, floating point and new components. The Hobbyist/Student version is limited to 4K of code (8K on 18F devices)



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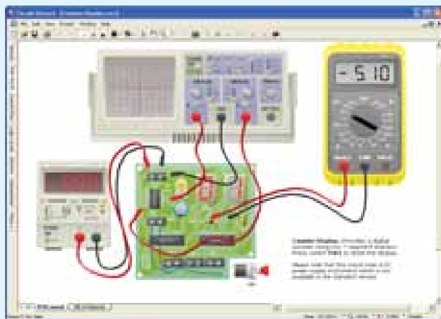
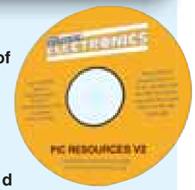


This is the software used in our *Teach-In 2011* series.
Standard **£61.25** inc. VAT
Professional **£91.90** inc. VAT

Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 2000/ME/XP, mouse, sound card, web browser.

EPE PIC RESOURCES V2



Version 2 includes the EPE PIC Tutorial V2 series of Supplements (EPE April, May, June 2003)

The CD-ROM contains the following Tutorial-related software and texts:

- EPE PIC Tutorial V2 complete series of articles plus demonstration software, John Becker, April, May, June '03
- PIC Toolkit Mk3 (TK3 hardware construction details), John Becker, Oct '01
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Net Work

Alan Winstanley

Radio Ga-Ga

LAST month, I shone some light on the networking technologies that are heading our way, including mains-borne networking using Homeplug or Homegrid devices. The Homeplug Power Alliance (Sony, LG, TI, ST, Maxim, Netgear, Devolo and more) follow the IEEE 1901 standard, while the Homegrid Forum (BT, Intel, Telefonica and more) went down the road of the ITU G.hn protocol instead. A low power Green PHY sub-set has energy-saving metering and Smart Grids in mind. I learned that it's theoretically possible to mix different brands of Homeplug adaptors together, but sometimes mains-borne networking would not work at all.

Reader Terry Mowles reminded me of the decade-long debate by the amateur radio associations, Radio Society of Great Britain (**www.rsgb.org/plt/**) and others to have power line technology either outlawed or forced to comply with the current EMC laws. In the UK, vociferous critics of this mains-borne technology include radio amateurs, with claims and counter-claims of interference being caused by power line technology to HF radio bands, emergency services and civil aviation communications. There's even the suggestion that street lamp-posts could become low-power radio beacons transmitting HF data.

The RSGB fears that power line adaptors could create an 'electronic smog' needing its own 'Clean Air' legislation. They published a lengthy discussion document voicing their concerns at **http://tinyurl.com/6l8kdv3**. Power line transmission clearly has its ardent critics, and it will be interesting to see how this marketplace evolves over time.

As broadband has rolled out and we gradually bury ourselves in a myriad of networked AV equipment, hooked together in a nest of HDMI (High Definition Multimedia Interface) and Ethernet cables, it's now possible to stream selected Internet-based services, such as BBC iPlayer, Facebook, Skype, Netflix and YouTube, direct to suitably equipped TV sets. This permits recent TV programmes to be replayed on a large modern TV, and video on demand or sports programmes, delivered by broadband direct to an Internet-enabled TV, is increasingly common.

However, one might need to keep an eye on monthly usage allowances in case TV or YouTube usage tips you over your allowed traffic quota. More options are being offered all the time as media barons strive to squeeze more out of our broadband connections.

Domotically-enhanced

The area of *domotics* relates to home automation, and viewers of TV's 'Grand Designs' program will doubtless have seen fanciful interiors of ultra-modern houses, with all manner of lighting, ventilation, heating, music, TV and more controlled by a touch screen. It's now possible to control a 'domotically-enhanced' house using an iPad or iPhone app (eg, Domotica from Ingegni, see **www.ingegnitech.com/en/domotica**). A number of mains, wireless and bus-based systems are already available. They offer the home automation enthusiast plenty to go at, and doubtless the price will eventually fall.

Peripherals that run on a home entertainment network have also arrived on the market. Sony's SMP-N100 network audio-video player, for example, is both Ethernet and WiFi enabled, allowing you to stream your AV content around the home, and even control it with an iPhone, iPod or some Android-based mobile phones.

Sony SMP-N100 media player points the way towards running a domestic network to host your music, video and photos

Rear view of Sony SMP-N100 showing, LAN, video and HDMI ports to connect to the latest multimedia equipment.

It's in our DLNA

Trying to plumb a complex HD system together, especially when differing brands of goods are used, could present its own problems, something which the Digital Living Network Alliance hopes to overcome. Just as computer-technology USB devices are plug-and-play interoperable, in the digital media world DLNA-certified devices strive to work together while avoiding compatibility problems. If you are contemplating updating your A/V equipment, then dipping your toes at **www.dlna.org** will help avoid you making costly mistakes in the future, and show you what to look for.

Some stand-alone network drives such as Western Digital's DLNA-compatible 'Live' are optimised to serve out your precious media collection over a DLNA-certified network. They use twin RAID-style drives to back up data, and you could stream video to your DLNA-compliant Xbox or large-screen TV, or play your music collection on an Ipad. How about displaying your photo albums over the home network, using WiFi enabled digital photoframes? Nor are you tied to your own household: using remote access over the web, you can log into your system from anywhere and access files that way.

One consideration is the intrinsic and sentimental value of your media data. As BBC iPlayer users already know, media such as some TV shows or music, which are secured by Digital Rights Management (DRM) cannot be copied onto other drives. RAID drives themselves offer no cast-iron guarantee of total data protection either. Rather, protection is provided on the basis that if one drive fails then the other drive (hopefully) keeps running, which saves your data

from total loss. At that point, you have to drop what you're doing and back up your data and rebuild the RAID drive array promptly. (Consider whether your domestic insurance policy covers this eventuality).

Online backups make a lot of sense, and Amazon offers 5GB free on its 'Cloud Drive' network. If you purchase MP3s from Amazon then they can be backed up automatically on your Cloud Drive, and Amazon's new Cloud Player streams music direct onto your Android phone or tablet, Mac or PC.

For the PC enthusiast who has a collection of media files to manage, Windows Home Server 2011 could be the solution. This fast-maturing home platform from Microsoft lets you stream your media files over a network and also backs them up automatically. A range of PCs optimised for use as a home media server are available, including HP's MediaSmart server range.

With an endless influx of new standards and technologies, installing a new media system in the home will increasingly see us talking of network 'clients' and 'servers' and 'network attached storage', configuring Ethernet and WiFi instead of hooking coax cables or phono leads/plugs together. I sense a new job title of 'Domestic Network Administrator' coming into vogue, with RAID rebuilding skills and lots of spare time considered desirable!

Embedded processors appear even in the most mundane of appliances, and Russian password-recovery specialist Elcomsoft explains how they could all be harnessed for the purposes of forensically breaking passwords. Elcomsoft already realised how the graphics CPUs resident in PCs can share the computational burden of the main CPU for this type of task.

They claim that home video consoles such as the Nintendo and Playstation can outgun many a PC, and as many domestic devices now have an embedded OS, it's worth pausing for thought when they mention digital photo frames, coffee makers, SLR digital cameras and more. Many such domestic devices, claims Elcomsoft, are over-engineered in terms of utilising a computing capacity that is way beyond the level required for the task in hand.

Elcomsoft's proposal is, therefore, to utilise these spare computing cycles in the almost surreal environment of a home cloud digital network. You can read more at **www.elcomsoft.com/home_cloud_computing.html**.

That's all for this month's *Net Work*. You can contact me at: **alan@epemag.demon.co.uk**

READOUT

Email: editorial@wimborne.co.uk

Matt Pulzer addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

All letters quoted here have previously been replied to directly

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★ LETTER OF THE MONTH ★

Interference from mains-borne networking

Dear Editor

Your columns on home networking have been interesting, but there is one point about them you may have missed.

There is currently a large debate and push by the amateur radio associations, RSGB (Radio Society of Great Britain) and individuals either to have them made illegal or comply with the current EMC laws.

Some manufacturers are pushing for an exemption from EMC legislation. In their current form, they do not comply with the EMC regulations, producing far in excess of the allowable interference to radio reception. This interference has been known to interfere with emergency services communications.

Living in Australia, I can't point you to any local sources of information other than the RSGB, but there is a reasonable amount posted on the Internet.

Terry Mowles, by email

Alan Winstanley replies:

I've touched upon Homeplug in the past and was made aware of some of the criticism of the technology due to the possibility of interference. This is an important aspect, given that all electrical devices sold in the EU have to be CE approved – meaning that, among other things, they have to neither generate interference nor be adversely affected by any interference that they might be subjected to.

Possibly more extensive testing is needed, and it will be interesting to see whether the regulations are manipulated or relaxed in order to accommodate this form of mains-borne networking.

Current burden

Dear Editor

The design of the current adapter for multimeters by David L Jones in May's *EPE* is very good and a useful add-on to a DMM.

It brings to light the principle that no measurement can be made without affecting the quantity measured by the act of measurement. The design presented shows how that effect can be reduced for the case of current measurement by inserting a series resistor and measuring the volt drop.

This, however, set me thinking about the case where the current is measured by means of its magnetic field to minimise the effect of the measurement. My old AVO has a 50μA moving-coil meter, which drops 125mV for full-scale reading due to the resistance of the coil. If it was made from a superconductor operating with zero resistance, would it drop 0V at 50μA?

This seems to suggest that in the steady state there is no 'burden'. However, the energy required to move the coil must come from the circuit during the time when the coil is moving from rest and back-EMFs are induced.

So presumably there is a transient 'burden'. If a Hall effect device is used to detect the current via its magnetic field, what is the mechanism for the current to detect that it is being measured and hence feel the effect of the measurement?

Ken Naylor, by email

Thank you for your interesting enquiry Ken. You are right, all observations will 'disturb' the observed, an effect of particular significance in quantum physics and described by the Heisenberg uncertainty principle. While EPE *readers may not be interested in measuring parameters on the atomic scale, it is always worth remembering that a measurement should interfere as little as possible with what is being measured.*

A Hall effect device will interact with a magnetic field and hence it will, to a small extent, draw power from the circuit, altering the value of current slightly. However, the effect is small and can usually be discounted – a more serious question is how can you calibrate the Hall effect current-measuring device, given that its ouput will vary with the angle of its orientation in three dimensions.

I must confess that I have never fully got to grips with the strange world of superconductivity – I have always been 'scared off' by an observation from a physicist cousin of mine: 'Only three people really understand superconductivity; one of them is mad and the other two don't agree'.

More on PIC/Excel communication

Dear Editor

When I sent my initial email regarding the import of data to MS Excel from a PIC, I did not expect the number and quality of the responses published in *EPE*. I am therefore pleased to see these.

However, what I was looking for, and I am convinced I saw it done in *EPE* many years ago, is the 'live' import into MS Excel without going down the intermediary route of sending the data to a temporary holding file first, and then importing it into Excel as a second operation. I believe such a technique was in either an *Interface* or *PIC 'n Mix* article.

I have taught myself JAL for PICs and have been able to get a PIC 16F88 to measure and convert analogue voltages and send them as csv files to a PC via an RS232 serial connection, as was suggested by respondents to my letter.

If one of your readers can remember the article and point me to it, or give information on configuring MS Excel to receive RS232 data directly I would appreciate it.

Many thanks from a long time reader/subscriber of *EPE*.

Bob White, Clevedon

Last call for those with long memories – anyone remember an article with the technique Bob describes?

Dear Editor

Following up on the Bob White/David Hannaford letters about capturing data into Excel. I have, recently, been involved in converting data from files and inserting it into Excel workbooks using the VSTO (Visual Studio to Office) API in VB.Net 4.0. Using this interface, it is a simple matter to open a workbook, insert data and format cells and then saving the result using only a small number of VB.net commands.

Using VSTO and .Net, Bob would not need to extract the data from Hyperterm, into files, before importing it into Excel.

VSTO is a Microsoft API and is fully supported under the .Net framework.

Regards, Liam Collins

Thank you Liam; another useful technique to consider.

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The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last book page.

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The series is aimed at those using PIC microcontrollers for the first time. Each part of the series includes breadboard layouts to aid understanding and a simple programmer project is provided.

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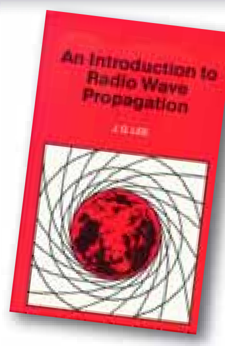

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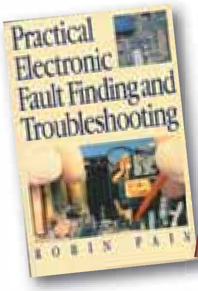

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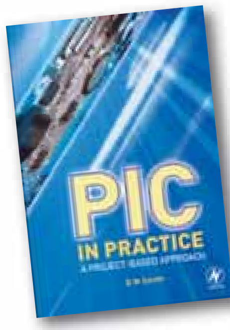

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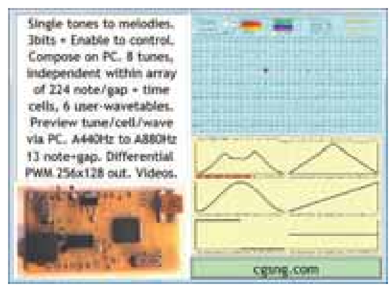

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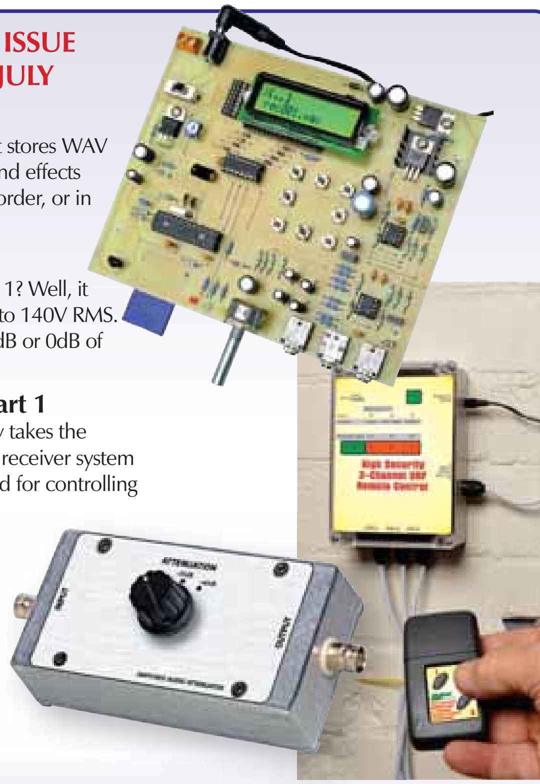

SD Card Music & Speech Recorder/Player

This is a fantastic project with a multitude of uses. It's a digital recorder that stores WAV files on low-cost MMC/SD/SDHC cards. It can be used as a jukebox, a sound effects player or an expandable 'Dictaphone'. You can use it as a freestanding recorder, or in conjunction with any Windows, Mac or Linux PC.

Input attenuator for the Digital Audio Millivoltmeter

Remember our super Digital Audio Millivoltmeter project back in March 2011? Well, it just got even better! With this add on you can now measure AC voltages up to 140V RMS. Easy to build, it's a simple switched-input divider that lets you add 40dB, 20dB or 0dB of attenuation ahead of the meter at the touch of a knob.

Deluxe 3-channel UHF Rolling Code Remote Control – Part 1

We've shown you how to make keyless entry systems before, but this really takes the concept to another level. It's a high-security 3-button UHF transmitter and receiver system that can be used for keyless entry into homes and commercial premises and for controlling garage doors and external lighting. Three separate outputs on the receiver can be used to activate various electrical devices, such as a door strike, a motorised garage door and 230V AC lights. Up to 16 transmitters can be used with one receiver, so it's even suitable for a small business.

Reycle It!

More free electronics from valuable discards!

Teach-In 2011 – Part 10

Mike and Richard Tooley discuss practical aspects of test instruments, measurements and testing circuits. Plus, you definitely do not want to miss their introduction to PCB layout using the series' excellent accompanying software package, Circuit Wizard.

Content may be subject to change

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